5 Human Health Risk Assessment

5.1 Overview

This section presents the baseline human health risk assessment for the Lower Fox River and Green Bay system. The baseline risk assessment quantitatively evaluates cancer risks and noncancer health hazards associated with exposure to chemicals in fish, waterfowl, sediment, surface water and air in the Lower Fox River and Green Bay. This risk assessment fulfills the NRC (2001) recommendation that sites be evaluated using a scientific risk-based framework so that different approaches for remediating PCB-contaminated submerged sediments can be compared in terms of the efficacy and human and ecological risks associated with each approach. A number of potential receptors are evaluated in this baseline risk assessment, but the receptors that experience the highest calculated cancer risks and noncancer health hazards are individuals who consume fish from the river and bay that are contaminated with PCBs. The baseline risk assessment evaluates potential risks and health hazards for baseline conditions in the absence of any remedial action or institutional controls, such as fish advisories, that might alter the behavior of receptors. Relative risks associated with other potential remedial actions are discussed in the Feasibility Study.

The baseline human health risk assessment uses the results of the Screening Level Risk Assessment (SLRA) (RETEC, 1998b) as a starting point. The human health evaluation in the SLRA presented a conceptual site model that identified potential sources of chemicals to the Lower Fox River, migration routes for chemicals through the Fox River and into Green Bay, and receptors (e.g., representative groups of people that could be exposed to chemicals in sediment, surface water, or air) for the Lower Fox River and Green Bay. The human health evaluation in the SLRA compared the concentrations of chemicals in fish tissue, waterfowl tissue, and sediment to Risk-Based Screening Concentrations (RBSCs). The chemicals with the most significant exceedances of RBSCs were retained for more detailed evaluation in the baseline human health risk assessment (Lynch and Webb, 1998). These chemicals of potential concern (COPCs) are:

- PCBs (total and/or Aroclor 1242),
- Dioxins,
- Furans,
- DDT/DDE/DDD,
- Dieldrin,
- Arsenic,

- Lead, and
- Mercury.

Section 5.2 begins by restating the conceptual site model from the human health evaluation in the SLRA. A major part of the conceptual site model is the identification of potential receptors and exposure pathways. The receptors are:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

Following the presentation of the conceptual site model, the results of the SLRA for polynuclear aromatic hydrocarbons (PAHs) are revisited. In the SLRA, PAHs were screened out. This screening was based, in part, on the fact that PAHs, although lipophilic like PCBs, dioxins/furans, dieldrin, DDT, DDE, and DDD, are metabolized by fish. Therefore, although PAHs were detected in sediments, they are not expected to bioaccumulate and biomagnify up the food chain as PCBs, dioxins/furans, and chlorinated pesticides do. At the time of the SLRA, there were no data for PAHs in fish. In the fall of 1998, fish samples were submitted for analysis and the results of these analyses are reviewed in Section 5.3. The evaluation indicates that PAHs were detected infrequently in fish samples and the risks associated with ingestion of fish containing PAHs are two orders of magnitude lower than those associated with ingestion of fish containing PCBs.

Following the conceptual site model, the intake equations, and intake assumptions used to estimate intakes for each receptor are presented (Section 5.4). Next, the procedures used to develop exposure point concentrations are presented in Section 5.5, which also summarizes the field data used in the risk assessment.

To evaluate the calculated intakes, dose-response functions are needed for each COPC. Dose-response information is provided in the dose-response assessment, including critical health effects for each COPC, cancer slope factors, and reference doses (Section 5.6).

Section 5.7 provides a baseline risk characterization, where the calculated intakes are combined with the dose-response information to calculate human health cancer risks and noncancer hazard indices for each receptor. These cancer risks and hazard indices are generated for different reaches in the Lower Fox River and for Green Bay. The highest cancer risks and hazard indices are calculated for recreational anglers and high-intake fish consumers due to ingestion of fish containing PCBs. These risks and hazard indices are more than 10 times higher than the risks and hazard indices for the next most exposed receptor, the hunter.

Lead was identified as a COPC in the SLRA, but lead cannot be evaluated by conventional risk assessment techniques. Specifically, lead is not evaluated as a carcinogen and there are no reference doses for lead. Instead, potential health effects for lead are evaluated using phamacokinetic models. In Section 5.8, the lead data in each medium is revisited in greater detail. The result of this evaluation is that lead is not considered to be of concern from a human health perspective in any medium.

The baseline risk characterization in Section 5.7 indicates that the highest cancer risks and noncancer hazard indices are for anglers as a result of exposure to PCBs from ingestion of fish. A detailed evaluation of such exposures is provided in Section 5.9. In this evaluation, the fish concentration data is investigated in more detail, a range of intake assumptions for recreational anglers and high-intake fish consumers are presented, and the cancer risks and hazard indices for exposure to different fish species using the range of intake assumptions are also presented. This section also provides a probabilistic risk assessment, an evaluation of a risk assessment performed by Exponent (2000) for the Fox River Group, and an evaluation of the potential for young children to experience adverse health effects from exposure to PCBs. Finally, this section provides risk-based concentrations of PCBs in fish for different cancer risk and hazard index values.

Section 5.10 provides an uncertainty and sensitivity analysis that describes the uncertainties and limitations in the data sets and the effects of different assumptions on the results.

Section 5.11 provides a summary of the human health risk assessment.

5.2 Sources, Migration Routes, Human Receptors, and Exposure Pathways

There are a large number of people who are potentially exposed, either directly or indirectly, to chemicals in the Lower Fox River and Green Bay. Land use along the Lower Fox River currently includes a mixture of agricultural, residential, light and heavy industrial, conservancy, and wetland areas. The Lower Fox River valley once had and may still have the greatest concentration of pulp and paper industries in the world, with numerous paper mills located on the 40-mile stretch of the Lower Fox River. Numerous townships, villages, and cities are located along the Lower Fox River. This corridor from Lake Winnebago to Green Bay, including the counties around Green Bay, is the second-largest urbanized area in the state of Wisconsin, with a population of about 640,000 (Census Bureau, 1992). The SLRA identified the greatest risk resulting from ingestion of fish containing PCBs. Based on information supplied by the Wisconsin Department of Natural Resources for 1999 (WDNR, 1999d), the following number of fishing licenses were issued in counties encompassing the Lower Fox River or bordering Green Bay.

Brown	36,633
Calumet	3,950
Door	7,506
Kewaunee	3,758
Marinette	16,013
Oconto	11,486
Outagamie	31,812
Winnebago	25,136

The total number of licenses in these counties is 136,294. Brown and Outagamie counties encompass the Lower Fox River and have a total of 68,445 licenses.

Figure 5-1 illustrates potential source media, migration routes, exposure media, and human receptors for chemicals present in the Lower Fox River and Green Bay system. Chemicals enter the Lower Fox River from a variety of sources. The primary sources of toxic chemicals are industrial and municipal wastewater discharges, discharges from stormwater systems, flows from tributary water bodies (i.e., Lake Winnebago, rivers, creeks, and streams), discharges from groundwater, and atmospheric deposition. The SLRA identified that the greatest risk associated with the Lower Fox River was exposures associated with ingestion of fish containing PCBs. The principal source of PCBs has been from discharges of industrial wastewater. Once in the Lower Fox River, chemicals such as PCBs may partition to bottom sediments, be associated with suspended sediments, or be dissolved in surface water. As water and sediment migrate downstream, chemicals will also migrate, eventually discharging to Green Bay. Once in Green Bay, the migration process will continue through the bay, although deposition of suspended sediment is more prevalent since water flow in Green Bay is considerably slower than in the Lower Fox River. Chemicals in Green Bay will continue to migrate in the dissolved and suspended particulate phases to Lake Michigan. This process is considerably slower than the migration of chemicals in the Lower Fox River, since the flow of water is considerably slower in Green Bay than in the Lower Fox River. Chemicals may also volatilize from surface water to air or may be transformed by chemical and microbial processes. Finally, chemicals, such as PCBs, may bioaccumulate and biomagnify through the food chain from sediment and surface water to aquatic vegetation, benthic organisms, fish, and waterfowl.

Once chemicals have entered the Lower Fox River and Green Bay system, exposures can occur to people through a variety of mechanisms. Table 5-1 provides a list of human receptors and exposure pathways that are considered in the human health risk assessment. These receptors are:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users, and
- Marine construction workers.

These receptors and their associated exposure pathways are also presented on Figure 5-1.

Recreational anglers, which includes a subset of high-intake fish consumers, are individuals who fish in the Lower Fox River and Green Bay. The Lower Fox River supports a variety of sport and non-sport fish. Sport fish species observed in the Lower Fox River include walleye, black crappie, northern pike, perch, bass, and catfish. Non-sport fish include carp, gizzard shad, freshwater drum, and white sucker. Similar fish species have been observed in Green Bay; in addition, salmon, sturgeon, lake trout, and burbot are commonly found there. Recreational anglers may be exposed to constituents in the river, such as PCBs, through ingestion of fish, inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water during fishing, and dermal contact with water during fishing. The exposures via water ingestion and dermal contact are likely to be sporadic, since recreational anglers are not intentionally entering the water.

High-intake fish consumers are individuals in the recreational angler population that eat significantly more fish than typical recreational anglers. High-intake fish consumers include individuals who would not be able to meet their daily nutritional requirements if they could not supplement their diet with sport-caught fish. Such high-intake fish consumers have often been termed subsistence anglers. In particular, Native Americans, Hmong, and Laotians may have portions of their populations engaged in subsistence fishing. Regardless of racial or ethnic background, individuals with low incomes are more likely to engage in high levels of fish consumption, often greater than the average recreational angler. The exposure pathways for the high-intake fish consumer are the same as those for the recreational angler.

Consumption of fish caught in the Lower Fox River/Green Bay has been recognized as a health issue since 1977, when the first fish advisories were issued. Fish advisories are still in effect for PCBs in the Lower Fox River and Green Bay (WDH/WDNR, 1998). Current fish advisories for PCBs are summarized in Table 5-2. These fish advisories are based on the relationship between tissue concentrations of PCBs in individual size classes and species of fish, and on a health protective value of 0.05 microgram of polychlorinated biphenyl per kilogram of body weight per day (μg-PCB/kg-BW/day) (as described in Anderson *et al.*, 1993). This value falls between the reference doses for Aroclor 1254 (0.02 μg-PCB/kg-BW/day) and Aroclor 1016 (0.07 μg-PCB/kg-BW/day) as discussed later in this section. This value is also consistent with a lifetime cancer risk level of about 10^{-4}. The fish advisories have been developed with the knowledge that there are significant nutritional benefits from eating fish. Fish are an excellent source of protein and are low in saturated fats (WDH/WDNR, 1998). Thus, the advisories have been developed with the understanding that there is a trade-off between consuming fish and being exposed to PCBs, on the one hand, and consuming fish and experiencing the nutritional benefits of the fish as a food source, on the other hand. With that trade-off in mind, the advisories describe precautions that should be taken by anglers and their families before consuming fish that have been caught from the Lower Fox River or Green Bay. These advisories are for trimmed and skinned fish, and assume an average meal size of 227 grams (0.5 pound) for a 70-kg adult based upon findings in a variety of studies of fish consumption, as discussed in detail later in this section. In addition, the fish advisory document (WDH/WDNR, 1998) provides advice for properly trimming, skinning, and cooking fish to reduce potential exposures to PCBs and other lipophilic chemicals. Despite these fish advisories, a high percentage of anglers and their families are often unaware of specific advisories and others choose to ignore them (West *et al.*, 1989, 1993). Tilden *et al.* (1997) found that 60 percent of women and 80 percent of ethnic minorities who had eaten sport fish were unaware of fish consumption advisories.

Hunters are individuals who hunt waterfowl in the Lower Fox River and Green Bay. These individuals may be exposed to chemicals through ingestion of waterfowl. Like anglers, these individuals may also be exposed to constituents in the river through inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water during hunting, and dermal contact with water during hunting. The exposures via ingestion and dermal contact are likely to be low for this receptor, since hunters may not come in contact with the water at all.

It should be noted that hunters may also hunt mammals, such as deer, that may eat vegetation, drink water, and contact sediment along the Lower Fox River or Green Bay. However, deer are likely to obtain only a small fraction (which may approach zero) of their daily food requirement from vegetation in the Lower Fox River or Green Bay. Therefore, deer are likely to have lower exposure to constituents in the Lower Fox River and Green Bay than waterfowl. This is true despite the fact that waterfowl are migratory and only spend a portion of the year in the Lower Fox River and Green Bay area. Additionally, it is difficult to determine the extent to which chemical concentrations in deer are due to exposure to chemicals in the Lower Fox River and Green Bay as opposed to exposure to chemicals in other areas, such as forested areas and farm fields. Therefore, the evaluation of hunters has been limited to hunting waterfowl.

Drinking water users are individuals that use water taken directly from the Lower Fox River as a source of drinking water. Lake Winnebago is used as a primary source of drinking water, but no part of the Lower Fox River is used as a primary water source. From Lake Winnebago to the dam at Appleton, the Lower Fox River serves as a secondary source of drinking water for the communities of Neenah, Menasha, and Appleton. All river water is treated prior to joining the water-distribution systems in these communities. From the dam in Appleton to the discharge point at Green Bay, the Lower Fox River is not used as a drinking water source. Green Bay is classified as a drinking water source, but does not actually supply drinking water to any communities near the Fox River. The city of Green Bay acquires its drinking water from Lake Michigan. The nearest community that takes water from Green Bay is Marinette, which is 40 to 50 miles from Green Bay. Potential exposures associated with direct use of water include ingestion; dermal contact during bathing, cooking and other household uses of water; and inhalation of chemicals volatilized into the air during showering and other uses.

Local residents are individuals who live next to the Lower Fox River or Green Bay. There are homes located along the water throughout the length of the Lower Fox River, except in downtown Green Bay. Potential exposures associated with living next to the river include inhalation of chemicals volatilized into the air from the surface water.

Recreational water users are individuals who wade, swim, jet ski, or water ski on the river or in the bay. Several parks are located on the Lower Fox River shoreline, although there are no public beach areas on the river where people are known to swim. Nonetheless, the potential exists for swimming to occur in the river. There are a number of public beaches in Green Bay. Potential exposures associated with recreational water use include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water, dermal contact with water, incidental ingestion of sediment, and dermal contact with sediment or sediment pore water.

Marine construction workers are individuals engaged in dredging or construction activities within the river or bay. These activities could include navigational dredging of the harbors on Lower Fox River or Green Bay, and construction projects that may occur in the river and along the Green Bay shoreline. Potential exposures associated with construction activities or navigational dredging include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of and dermal exposure to water during work activities, and incidental ingestion of and dermal exposure to sediment during work activities.

Table 5-1 lists the primary receptor groups and their associated exposure pathways for the Lower Fox River and Green Bay. While more receptor groups could have been developed, the human health assessment has focused on the dominant receptor groups and exposure pathways. It is possible for an individual to live next to the river (the local resident), use the river for recreational activities (the recreational water user), fish from the river (recreational angler), hunt waterfowl from the river (hunter), and obtain drinking water from the river (drinking water user). The exposures to such an individual would be a combination of the exposures to the five receptor groups identified in parentheses. Such an individual is likely to be rare and, therefore, is not discussed in detail in the risk characterization. However, such rare receptors are mentioned in the uncertainty analysis. The primary goal of Table 5-1 is to identify key receptor groups so that potential risks can be estimated for representative receptors in the Lower Fox River and Green Bay.

5.3 Evaluation of Polynuclear Aromatic Hydrocarbons (PAHs) in Whole Body Fish Tissue Samples

In September 1998, whole body fish tissue samples were collected and analyzed for polynuclear aromatic hydrocarbons (PAHs), PCBs, pesticides, and dioxins/furans. The fish species sampled were carp, walleye, and shiners, and the samples were collected from the following three reaches: Little Lake Butte des Morts, Little Rapids to De Pere, and De Pere to Green Bay. This sampling was conducted in order to provide supplemental data for the risk assessment. This data included analysis for PAHs in fish tissue, which previously had not been analyzed. The samples were analyzed for additional chemicals including PCBs and 2,3,7,8-TCDD.

A summary of selected results of the supplemental sampling is presented in Table 5-3. This table indicates the maximum detected concentration, the average concentration, and the frequency of detection of each PAH constituent analyzed in the fish tissue samples. The results for total PCBs and 2,3,7,8-TCDD are also listed in this table to provide some comparative information.

5.3.1 Screening Evaluation

Next, a screening evaluation was performed on these data to determine the potential for adverse human health effects. As was done in the Screening Level Risk Assessment, each constituent is compared to its risk-based screening concentration (RBSC). The RBSCs for the fish ingestion scenario are based on conservative exposure assumptions for high-intake fish consumers (RETEC, 1998b). It should be noted that in RETEC (1998b), high-intake fish consumers are referred to as "subsistence anglers," and the subscript "SA" is an abbreviation for a "subsistence angler." The equation and exposure parameters used to calculate high-intake fish consumers RBSCs ($RBSC_{SA\text{-}fish}$) for carcinogenic chemicals are as follows:

$$RBSC_{SA\text{-}fish} = \frac{TR \times BW \times ATc}{FIR \times EF \times ED \times FI \times SF}$$

where:

- TR = target risk = 1.0×10^{-6},
- BW = body weight = 70 kg,
- ATc = averaging time (carcinogenic) = 25,550 days,
- FIR = fish ingestion rate = 0.14 kilograms per day (kg/day),
- EF = exposure frequency = 365 days per year (days/yr),
- ED = exposure duration = 70 years,
- FI = fraction ingested from Fox River = 100%, and
- SF = oral cancer slope factor (chemical-specific).

The equation and exposure parameters used to calculate high-intake fish consumer RBSCs ($RBSC_{SA\text{-}fish}$) for non-carcinogenic chemicals are as follows.

$$RBSC_{SA\text{-}fish} = \frac{THQ \times BW \times ATnc \times RfD}{FIR \times EF \times ED \times FI}$$

where:

- THQ = target hazard quotient = 0.1,
- $ATnc$ = averaging time (non-carcinogenic) = 25,550 days, and
- RfD = chronic oral reference dose (chemical-specific).

The other parameters in the equation were defined above.

Exposure assumptions used to calculate the $RBSC_{SA\text{-}fish}$ are consistent with the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993), which has been adopted by all eight states in the Great Lakes basin. An average daily fish ingestion rate of 140 grams per day (g/day) was used to calculate the $RBSC_{SA\text{-}fish}$; this corresponds to the ingestion rate assumed in Anderson *et al.* (1993) for unrestricted consumption of sport fish. It is also the maximum fish consumption rate assumed for anglers in the 1996 Fox River Risk Assessment (GAS/SAIC, 1996), which was intended to be representative of a subsistence level of fish consumption. This ingestion rate (140 g/day) is comparable to EPA's default subsistence fish ingestion rate of 132 g/day (EPA, 1991a), and corresponds to about 4.3 meals per week (assuming a meal size of 227 grams, or 0.5 pound). An exposure duration of 70 years (corresponding to an average lifetime of 70 years) was assumed, consistent with Anderson *et al.* (1993). It should be noted that Anderson *et al.* (1993) used an average lifetime of 70 years, while EPA's Exposure Factors Handbook (1997b) revised this number to 75 years. For screening purposes, no reduction in constituent concentrations due to cooking and cleaning of fish was assumed.

Table 5-4 presents the oral reference doses and cancer slope factors that are available for the chemicals detected in fish tissue. These toxicity criteria were obtained from the EPA's Integrated Risk Information System (IRIS) or from the Health Effects Assessment Summary Tables (HEAST). For some PAHs, no toxicity criteria were available; therefore, surrogate criteria from structurally similar PAHs were used to calculate RBSCs. Table 5-4 also presents the calculated RBSCs for each chemical.

The results of the screening evaluation are presented in Table 5-5. For each PAH that was detected in fish tissue, the maximum detected concentration was compared to its corresponding $RBSC_{SA\text{-}fish}$. If the maximum detected concentration was greater than the $RBSC_{SA\text{-}fish}$, the chemical was identified as a potential constituent of interest for the fish ingestion pathway. If the maximum detected concentration was less than the $RBSC_{SA\text{-}fish}$, the PAH was eliminated from further evaluation for the fish ingestion pathway. The screening was also performed for total PCBs and 2,3,7,8-TCDD.

5.3.2 Calculation of Cancer Risks

As indicated in Table 5-5, the maximum detected concentrations of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceeded their respective RBSCs. For each of these PAHs, the cancer risk was calculated based on the maximum concentration and the exposure assumptions used to derive the RBSC. The equation used to calculate the cancer risk is as follows.

$$Cancer\ Risk = \frac{Maximum\ Detection}{RBSC_{SA-fish}} \times 10^{-6}$$

This calculation was also done for total PCBs and 2,3,7,8-TCDD, whose maximum concentrations exceeded their respective RBSCs.

The calculated cancer risks for each chemical with a maximum detected concentration above the RBSC are also presented in Table 5-5. Only two of the PAHs, benzo(a)pyrene and dibenz(a,h)anthracene, were found to have associated cancer risks above the 10^{-4} risk level. The calculated cancer risks for total PCBs and 2,3,7,8-TCDD also exceeded the 10^{-4} risk level. This risk level is associated with an increased chance of developing cancer of 1 in 10,000, and is the upper end of the range of acceptable risks (10^{-6} to 10^{-4}) that is generally used when making cleanup decisions under Superfund.

5.3.3 Results of PAH Evaluation

Although the results of this evaluation show that two PAHs may be present at levels exceeding a 10^{-4} cancer risk, several things should be noted. First, the calculated cancer risks are two orders of magnitude below those for PCBs. Second, each PAH was only detected in two out of 12 samples whereas PCBs were detected in all samples. Third, the data are for whole fish samples, while people eat, with rare exceptions, fillets. PAHs are readily metabolized, which is reflected in the low number of detections, and are less likely to accumulate in the fillet than in other organs of the fish. Thus, the use of whole body samples is conservative. Finally, the exposure assumptions used to calculate RBSCs and the associated risks are very conservative. Taking all this into account, actual exposure to PAHs from ingestion of fish is likely to be significantly below that estimated here and below that estimated for PCBs. Therefore, exposure to PAHs is not considered further.

5.4 Intake Assumptions for Potential Receptors

This section describes the intake assumptions used for calculating the intake by potential receptors in the Lower Fox River and Green Bay. This discussion is divided into three parts: the first part provides a general overview of intake assumptions; the second part presents intake equations applicable to the receptors in the river and bay; and the third part discusses assumptions used for specific receptors in the river and bay. The exposure assumptions presented are based primarily on EPA risk assessment guidance (EPA, 1989c, 1991a, 1997b).

5.4.1 Overview of Intake Assumptions

This section provides a general discussion of the assumptions used to calculate intakes from various exposure pathways. Exposure pathways are defined as a direct contact route between a receptor and an impacted medium. Exposure pathways are determined for receptors based on the receptors' expected activities at the site. In order to translate exposures to potentially impacted media into intakes or doses, intake assumptions must be specified. These intake assumptions consider the number of times a receptor is expected to contact a particular medium, the duration of the contact, and the mechanisms that enable chemicals in impacted media to be potentially assimilated by the receptor (EPA, 1989c, 1997b).

Generally, the intake or dose of a particular chemical by a receptor is calculated with the equation:

$$I = \frac{C \cdot CR}{BW} \cdot \frac{EF \cdot ED}{AT}$$

where:

I	=	the chemical intake (milligrams per kilogram of body weight per day [mg/kg-BW/day]),
C	=	the chemical concentration (e.g., milligrams per kilogram of soil [mg/kg-soil] or milligrams per liter of water [mg/L-water]),
CR	=	contact rate or the amount of impacted medium contacted per event (e.g., liters per day [L/day]),
EF	=	exposure frequency (days/yr),
ED	=	exposure duration (years),
BW	=	the average body weight of the receptor (kg), and
AT	=	averaging time of the exposure (days).

This equation calculates an intake that is normalized over the body weight of the individual and the duration of the exposure.

Since the intake or dose is combined with quantitative indices of toxicity (chemical-specific dose-response information such as reference doses or cancer slope factors) to give a measure of potential health effects, the intake or dose must be calculated in a manner that is compatible with the quantitative dose-response information for the chemicals used in the analysis. Two different types of health effects are considered in this analysis: non-threshold (carcinogenic) effects and threshold (non-carcinogenic) effects.

For carcinogenic effects, the relevant intake is the total cumulative intake averaged over a lifetime, because the quantitative dose-response function for carcinogens is based on the assumption that cancer results from cumulative lifetime exposures to carcinogenic agents. The cumulative intake or dose is then averaged over a lifetime to provide an estimate of intake or dose of carcinogens expressed in units of milligrams per kilogram per day (mg/kg-day). Thus, for potentially carcinogenic chemicals, the averaging time (*AT*) is equal to 75 years (EPA, 1997b).

In this analysis, non-carcinogenic effects are evaluated for potential chronic exposures. The relevant intake or dose is based on the daily intake averaged over the exposure period. The quantitative dose-response function for non-carcinogenic effects is based on the assumption that effects occur once a threshold dose resulting from exposure is attained (EPA, 1989c). For non-carcinogenic effects, the averaging time (*AT*) is equal to the period of exposure for the receptor.

5.4.2 Generalized Assumptions for Exposure Analysis

In this section, the calculated intake or dose per event is discussed for seven routes of exposure: ingestion of fish, ingestion of waterfowl, ingestion of water, dermal contact with water, inhalation of volatiles, incidental ingestion of sediment, and dermal contact with sediment.

Ingestion of Fish

The intake or dose for the ingestion of fish pathway is calculated based on the equation (EPA, 1989c, 1997b):

$$I_{ing\text{-}f} = \frac{Cfish \cdot RF \cdot IR \cdot CF \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

$I_{ing\text{-}f}$ = intake from ingestion of fish (mg/kg-BW/day),
Cfish = chemical concentration in fish (milligrams per kilogram of fish [mg/kg-fish]),
RF = reduction factor (unitless),
IR = fish ingestion rate (grams of fish per day [g-fish/day]),
CF = conversion factor (10^{-3} kilograms per gram [kg/g]),
ABS = ingestion absorption factor (fraction absorbed),
EF = exposure frequency (days/yr),
ED = exposure duration (years),

BW = body weight (kg), and
AT = averaging time (days).

The concentrations of the chemicals in fish (*Cfish*) are discussed in Section 5.5. The reduction factor (*RF*) is a number between 0 and 1 that describes the fraction of the chemicals originally in the fresh caught fish remaining after the fish has been gutted, scaled, trimmed, and cooked. The ingestion rate (*IR*) is the amount of fish ingested per day or event. The absorption factor (*ABS*) is the fraction of chemical absorbed during ingestion and is chemical-specific, although it is generally assumed to be 100 percent. This assumption is also reasonable. The oral cancer slope factors and oral reference doses for COPCs are generally based on ingestion studies in animals. Therefore, it is expected that absorption from ingestion of fish will be similar to absorption in the animal study, so setting *ABS* to 100 percent is reasonable. For example, the cancer slope factors for PCBs are based on an oral feeding study (Brunner *et al*., 1996), the oral reference dose for Aroclor 1016 is based on oral feeding studies (Barsotti and Van Miller, 1984; Levin *et al*., 1988; Schantz *et al*., 1989, 1991), and the oral reference dose for Aroclor 1254 is also based on ingestion of PCBs in a gelatin capsule (Arnold *et al*., 1993a, 1993b; Tryphonas *et al*., 1989, 1991a, 1991b). Thus, absorption after ingestion of fish is likely to be similar to absorption in the studies used as the basis for the oral cancer slope factors and oral reference doses. The exposure frequency (*EF*), exposure duration (*ED*) and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

It should be noted that the chemical concentration in fish (*Cfish*), the reduction factor (*RF*) and the fish ingestion rate (*IR*) are closely related. This relationship is discussed briefly here and in more detail in Section 5.4.3. In this analysis, *Cfish* is the concentration of COPCs in raw fish, generally skin on fillet. The variable *IR* refers to the uncooked weight of the fish portion that is eaten. Trimming will reduce the mass of fish consumed and will reduce the concentration if fatty parts with higher concentrations are trimmed. Cooking will also reduce the mass of fish, principally through water loss, but also through volatilization of COPCs. In many cases, the overall tissue concentrations after trimming and cooking are similar to the concentrations in the raw, uncooked fish, but the mass of fish has been reduced, so the total mass of COPC in the cooked fish is less than in the uncooked fish. In other cases, the tissue concentrations of COPCs after trimming and cooking are less than the concentrations in the raw, uncooked fish. In these cases, the total COPCs in the fish portion has been reduced by concentration reduction as well as reduction in the mass of fish (Anderson *et al*., 1993).

Ingestion of Waterfowl

The intake or dose for the ingestion of waterfowl pathway is calculated based on the equation (EPA, 1989c, 1997b):

$$I_{ing-wf} = \frac{CWF \cdot RF \cdot IR \cdot CF \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

I_{ing-wf} = intake from ingestion of waterfowl (mg/kg-BW/day),
CWF = chemical concentration in waterfowl (milligrams per kilogram of waterfowl [mg/kg-waterfowl]),
RF = reduction factor (unitless),
IR = waterfowl ingestion rate (grams of waterfowl per day [g-waterfowl/day]),
CF = conversion factor (10^{-3} kg/g),
ABS = ingestion absorption factor (fraction absorbed),
EF = exposure frequency (days/yr),
ED = exposure duration (years),
BW = body weight (kg), and
AT = averaging time (days).

The concentrations of the chemicals in waterfowl (*CWF*) are discussed in Section 5.5. The reduction factor (*RF*) is a number between 0 and 1 that describes the fraction of the chemical originally in the waterfowl remaining after the waterfowl has been gutted, trimmed, and cooked. The ingestion rate (*IR*) is the amount of waterfowl ingested per day or event. The absorption factor (*ABS*) is the fraction of chemical absorbed during ingestion and is chemical-specific, although it is generally assumed to be 100 percent. As discussed for the fish ingestion pathway, this assumption is also reasonable since the oral cancer slope factors and oral reference doses for COPCs are generally based on ingestion studies in animals. The exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

As with ingestion of fish, the chemical concentration in waterfowl (*CWF*), the reduction factor (*RF*) and the waterfowl ingestion rate (*IR*) are closely related. This inter-relationship is investigated in the assumptions for the hunter, which are presented in Section 5.4.3.

Ingestion of Water

The intake or dose from ingestion of water is calculated using the equation (EPA, 1989c, 1997b):

$$I_{ing-w} = \frac{CW \cdot IR \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

I_{ing-w} = intake from ingestion of water (mg/kg-BW/day),
CW = concentration of chemical in water (milligrams per liter [mg/L]),
IR = ingestion rate (L/day),
ABS = ingestion absorption factor (fraction absorbed),
EF = exposure frequency (events per year [events/yr]),
ED = exposure duration (years),
BW = body weight (kg), and
AT = averaging time (days).

Concentrations of chemicals in water (*CW*) are discussed in Section 5.5. The ingestion rate (*IR*) is the amount of water ingested per day. The absorption factor (*ABS*) used in this equation is chemical-specific, but is generally assumed to be 100 percent. As discussed for the fish ingestion pathway, this assumption is reasonable since the oral cancer slope factors and oral reference doses for COPCs are generally based on ingestion studies in animals. The exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

Dermal Contact with Water

The absorbed intake or dose from dermal contact with water is calculated using the equation (EPA, 1992a):

$$I_{der-w} = \frac{CW \cdot SA \cdot PC \cdot ET \cdot EF \cdot ED \cdot CF}{BW \cdot AT}$$

where:

I_{der-w} = absorbed intake from dermal contact with water (mg/kg-BW/day),
CW = concentration of chemical in water (mg/L),
SA = exposed skin surface area (square centimeters [cm^2]) = $TBS \cdot FBE$,
TBS = total body surface area (cm^2),
FBE = fraction of body exposed (unitless),
PC = permeability constant (centimeters per hour [cm/hr]),
ET = exposure time (hours per day [hrs/day]),
EF = exposure frequency (days/yr),
ED = exposure duration (years),
CF = volumetric conversion factor (liters per 1,000 cubic centimeters [L/1,000 cc]),

BW = body weight (kg-BW), and
AT = averaging time (days).

The concentrations of chemicals in water (CW) are discussed in Section 5.5. The skin surface area (SA) exposed to water is the product of the total body surface area (TBS) and the fraction of body exposed (FBE). The variable FBE is highly dependent on the nature of the activity being conducted, ranging from nearly 100 percent for showering or swimming to 5 percent or less for workers contacting water during work activities. In addition, dermal absorption may vary for different skin types and locations on the body. The permeability constants (PC) are chemical-specific and describe the rate at which the chemical moves from water through the skin. The exposure time (ET), exposure frequency (EF), exposure duration (ED), and body weight (BW) are described in the intake assumptions for specific receptors. The averaging time (AT) was discussed previously.

The permeability constants (PC) were set to permeability coefficients or Kp values obtained from EPA's *Dermal Exposure Assessment: Principles and Application* (EPA, 1992a). In this guidance, measured values of Kp are available for some constituents. These values were used when available. For other constituents, values for Kp were calculated using the following chemical structure activity relationships (Potts and Guy, 1992, as reported in EPA, 1992a):

$$\log Kp = -2.72 + 0.71 \cdot \log K_{ow} - 0.0061 \cdot MW$$

In this equation, K_{ow} is the octanol-water partition coefficient and MW is the molecular weight in grams per mole (g/mole). The values for a number of organic COPCs were calculated in EPA (1992a) using this equation and are presented in Table 5-6. The value for PCBs is based on hexachlorobiphenyl, while the value for dioxins/furans is based on 2,3,7,8-TCDD. Values for inorganic compounds are also presented in Table 5-6. The value for arsenic is the default value for inorganics of 0.001 cm/hr (EPA, 1992a). The value for lead in Table 5-6 is a measured value for lead acetate provided in EPA (1992a). The value for mercury is a measured value for mercuric chloride (EPA, 1992a).

For PCB Aroclors, PCB congeners, dioxin congeners except 2,3,7,8-TCDD, and furan congeners, there were no values for Kp in EPA (1992a). Thus, values for Kp were calculated for these COPCs using the above equation. The inputs (K_{ow}, MW) and results (Kp) are presented in Table 5-7 for these COPCs. The sources of the K_{ow} and MW values were Mackay *et al*. (1992a, 1992b).

It should be noted that the structure activity relationship provided above was developed for chemicals with much higher solubilities and lower values of K_{ow} than the organic COPCs considered in this assessment. Therefore, there is significant uncertainty associated with the use of these permeability coefficients to assess dermal uptake from water.

Inhalation of Volatiles

For inhalation, the dose per event is estimated using the formula (EPA, 1989c, 1997b):

$$I_{inhal} = \frac{CA \cdot IR \cdot ABS \cdot ET \cdot EF \cdot ED}{BW \cdot AT}$$

where:

- I_{inhal} = intake from inhalation (mg/kg-BW/day),
- CA = concentration of chemical in air (milligrams per cubic meter [mg/m^3]),
- IR = inhalation rate (cubic meters per hour [m^3/hr]),
- ABS = inhalation absorption factor (fraction absorbed),
- ET = exposure time (hrs/day),
- EF = exposure frequency (days/yr),
- ED = exposure duration (years),
- BW = body weight (kg), and
- AT = averaging time (days).

The concentrations of chemicals in the air (*CA*) are the ambient air concentrations of chemicals volatilized from the surface water and are discussed in Section 5.5. The inhalation rate (*IR*) is the average rate of respiration for individuals per hour. This rate is dependent on the age and the average activity level of the individual and is selected specifically for each receptor. The inhalation absorption factor (*ABS*) is chemical-specific, but is assumed to be 1 (or 100 percent) for all chemicals and receptors, implying that all of the inhaled chemicals are assimilated into the body. This is an appropriately conservative and, consequently, health-protective assumption. This assumption is reasonable since inhalation cancer slope factors and inhalation reference doses are generally derived based on the delivered dose from inhalation and not the absorbed dose. Exposure time (*ET*), exposure frequency (*EF*), and exposure duration (*ED*) are dependent on the exposure scenario for the individual receptors and are defined in the intake assumptions for each receptor. The body weight (*BW*) is also receptor-specific. The averaging time (*AT*) was discussed previously.

Incidental Ingestion of Sediment

The intake or dose for the incidental ingestion of sediment pathway is calculated based on the equation (EPA, 1989c, 1997b):

$$I_{ing-s} = \frac{CS \cdot IR \cdot CF \cdot FI \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

I_{ing-s}	=	intake from incidental ingestion of sediment (mg/kg-BW/day),
CS	=	chemical concentration in sediment (milligrams per kilogram of sediment [mg/kg-sediment]),
IR	=	incidental sediment ingestion rate (milligrams of sediment per day [mg-sediment/day]),
CF	=	conversion factor (10^{-6} kilograms per milligram [kg/mg]),
FI	=	fraction of daily incidental sediment ingestion occurring on-site (unitless),
ABS	=	ingestion absorption factor (fraction absorbed),
EF	=	exposure frequency (days/yr),
ED	=	exposure duration (years),
BW	=	body weight (kg), and
AT	=	averaging time (days).

The concentrations of the chemicals in sediment (*CS*) are discussed in Section 5.5. The ingestion rate (*IR*) is the amount of sediment incidentally ingested per day or event. The fraction ingested (*FI*) is the percent of the daily intake of sediment that occurs at the site. The absorption factor (*ABS*) is the fraction of chemical absorbed during ingestion and is chemical-specific, but is generally assumed to be 1 (or 100 percent). The exposure frequency (*EF*), exposure duration (*ED*) and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

The sediment absorption factors used in this analysis are presented in Table 5-8. With one exception, these factors are 100 percent, which conservatively assumes all chemicals present in the sediment are absorbed to the same extent that the chemical was absorbed in the toxicological study or studies used as the basis for either the oral cancer slope factor or oral reference dose. While it is likely that chemicals are not absorbed as readily from ingested sediment as from food (the vehicle generally used in animal studies to deliver the chemical), no or very limited experimental studies exist for quantifying absorption from sediment or soil for any COPCs except arsenic. The absorption factor for arsenic was set to 32 percent based on a study by Freeman *et al.* (1993). The study by Freeman *et al.* (1993) evaluated the bioavailability of arsenic in soil, and these results are assumed to be applicable to sediment. The oral cancer slope factor for arsenic is based on epidemiological data for individuals exposed to high levels of arsenic in well water. In the study by Freeman *et al.* (1993), the bioavailability of arsenic via ingestion of soils was estimated to be 24 percent with a standard deviation of 3.2 percent (Freeman *et al.*, 1993). This bioavailability value was based on a comparison of excretion data from two groups of prepubescent male and female SPF New Zealand white rabbits, each of which was administered varying levels of arsenic either in soil or intravenously. The experimentally-derived bioavailability value of 24 percent for arsenic was adjusted upwards to 30 percent for this analysis, which is about two standard deviations above the mean and provides a conservative estimate of the bioavailability of arsenic in soil for the inadvertent ingestion scenarios. Since bioavailability in soil was measured relative to intravenously-administered arsenic, this absorption factor must be modified relative to the absorption of arsenic in the epidemiological study used to derive the cancer slope factors and reference doses. The absorption of arsenic from water is estimated to be 95 percent (Dollarhide, 1993). Thus, the soil absorption factor is 0.30/0.95, or 32 percent, and this value was used in this analysis for absorption of arsenic from incidentally ingested sediment.

Dermal Contact with Sediment

The absorbed intake or dose per event from dermal contact with sediment is estimated using the equation (EPA, 1989c, 1992b):

$$I_{der-s} = \frac{CS \cdot CF \cdot SA \cdot AF \cdot ABS \cdot FC \cdot EF \cdot ED}{BW \cdot AT}$$

where:

- I_{der-s} = absorbed dose from dermal contact with sediment (mg/kg-BW/day),
- CS = concentration of the chemical in sediment (mg/kg),
- CF = conversion factor (10^{-6} kg/mg),
- SA = exposed skin surface area (square centimeters per event [cm^2/event]) = $TBS \cdot FBE$,
- TBS = total body surface area (cm^2),
- FBE = fraction of the body exposed (unitless),
- AF = sediment adherence factor (milligrams per square centimeter [mg/cm^2]),
- ABS = skin absorption factor (unitless),
- FC = fraction of the day that contact with sediment occurs at the site (unitless),
- EF = exposure frequency (events/yr),
- ED = exposure duration (years),

BW = body weight (kg), and
AT = averaging time (days).

Concentrations of chemicals in sediment (*CS*) are discussed in Section 5.5. The skin surface area (*SA*) exposed to sediment is the product of the total body surface area (*TBS*) and the fraction of body exposed (*FBE*). The fraction of body exposed (*FBE*) is dependent on the nature of the activity being conducted and the age and type of the individuals involved. The sediment adherence factor (*AF*) is the density of sediment adhering to the exposed fraction of the body. The skin absorption factor (*ABS*) is the percentage of the chemical absorbed during dermal contact with sediment. The fraction of the day that contact occurs (*FC*) is the percent of time that sediment contact occurs at the site. The exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are receptor-specific. The averaging time (*AT*) was discussed previously.

The dermal absorption factors used in this analysis are presented in Table 5-9. EPA Region III performed a review of dermal absorption data and developed dermal absorption factors for absorption from soil for a number of chemicals (EPA, 1995a). Absorption factors are used to reflect the desorption of the chemical from soil and the absorption of the chemical across the skin and into the bloodstream (EPA, 1989c). The Region III guidance (EPA, 1995a) summarizes chemical-specific and general (for classes of compounds) absorption factors that have been found in the limited database available. The factors were compiled from existing national guidance and peer-reviewed scientific literature. It is recommended that these numbers be used as defaults for the *ABS* parameter when calculating reasonable maximum exposures (RME) to soil in the absence of chemical-specific and site-specific information (EPA, 1995a). For this evaluation, it was assumed that dermal absorption from sediment would be similar to dermal absorption from soil. A value of 6 percent is recommended for PCBs (EPA, 1995a). A value of 3 percent is recommended for chlorinated dioxins/furans based on the dermal absorption of 2,3,7,8-TCDD (EPA, 1995a). The 10 percent value is recommended as a conservative assumption of *ABS* for pesticides, including dieldrin and DDT and its metabolites (EPA, 1995a). A value of 3.2 percent is recommended for arsenic while 1 percent is recommended for all other metals and inorganics (EPA, 1995a).

5.4.3 Specific Intake Assumptions for Receptors

As discussed previously, the critical receptors associated with the Lower Fox River and Green Bay are:

- Recreational anglers,
- High-intake fish consumers,

- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users, and
- Marine construction workers.

A detailed discussion of the intake assumptions for evaluating potential exposures to these receptors is provided below. For some of these receptors, two exposure scenarios are presented: a reasonable maximum exposure or RME scenario (to represent high-end exposures) and a central tendency exposure or CTE scenario (to represent more typical exposures). Differences in intake assumptions for the two scenarios are described in the subsections below.

Overview of Key Assumptions for Anglers

This subsection provides detailed discussion of several intake parameters for the recreational anglers and high-intake fish consumers. These parameters are the daily fish ingestion rate (*IR*), exposure frequency (*EF*), reduction factor (*RF*), and exposure duration (*ED*). The parameters *IR* and *EF* are discussed separately for recreational anglers and high-intake fish consumers. The discussion of *ED* applies to the hunter as well as the two angler populations. All these parameters are discussed in detail in Appendix B1, where probability distributions for each parameter are presented.

Ingestion Rate and Exposure Frequency for Recreational Anglers. There are reportedly about 136,000 individuals with fishing licenses (WDNR, 1999d) who reside in counties immediately adjacent to the Lower Fox River and Green Bay. Ten percent of the angler population, or about 14,000 anglers, could be considered high-intake fish consumers (i.e., individuals who consume fish at more than the 90^{th} percentile of the distribution of fish ingestion rates). Table 5-10 summarizes intake assumptions for the general recreational angler population based on three surveys of the recreational angling population: a 1989 survey of Michigan anglers (West *et al*., 1989), a 1993 follow-up survey of Michigan anglers (West *et al.*, 1993), and a 1989 study of Wisconsin anglers (Fiore *et al*., 1989). Two types of intake assumptions are provided; one based on upper-bound values, termed the reasonable maximum exposure (RME) scenario, and one based on mean or median values, termed the central tendency exposure (CTE) scenario.

The intake assumptions which differ between the studies are the daily ingestion rate (*IR*) and the exposure frequency (*EF*). West *et al*. (1989, 1993) estimated the average amount of fish consumed at each meal (*IR*) by showing anglers a picture of an 8-ounce (227-g) portion of cooked fish and asked if they ate more, less, or about this much fish at each meal. The responses were used to derive a distribution of fish consumption per meal. West *et al*. (1989, 1993) also determined a distribution of the number of meals per year (*EF*) of sport-caught fish that were consumed. These data were combined by EPA (1997b) and SAIC (1995) in a probabilistic analysis to determine a distribution of fish consumed per day normalized over 365 days per year. These values of *IR* and *EF* are reported in Table 5-10 for the two West *et al.* studies. For the 1989 study, the 95th percentile for *IR* is 39 g/day (RME) and the mean is 12 g/day (CTE). Since the data were normalized over 365 days per year, *EF* is 365 days per year for both the RME and CTE scenarios. For the 1993 study, the 95th percentile for *IR* is 78 g/day (RME) and the mean is 17 g/day (CTE). Once again, since the data were normalized over 365 days per year, *EF* is 365 days per year for both the RME and CTE scenarios.

In the Fiore *et al.* (1989) study, the number of meals of sport fish consumed each year were determined. Fiore *et al.* did not determine the quantity of fish consumed in each meal during their study. However, the Wisconsin Department of Health and Social Services performed follow-up studies where various quantities of uncooked fish were shown to anglers and these studies demonstrated that a typical meal size is 8 ounces (227 grams) of uncooked fish. These studies are the basis for the 8 ounces of uncooked fish which is used in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.,* 1993) to determine acceptable concentrations of PCBs in fish. Again, it is important to note that all eight states in the Great Lakes basin have fish consumption advisories that have been developed in whole or in part using this protocol (Clark, 2000). With this background, the amount of fish consumed per meal (*IR*) was set to 227 g/day for both the RME and CTE scenarios. The number of meals consumed per year (*EF*) was set to 59 days/yr for the RME scenario and 18 days/yr for the CTE scenario.

Table 5-10 presents values of *IR* and *EF* for each study using the basis in each study. To allow intake assumptions to be compared directly, values of *IR* and *EF* are also provided for each study using common bases. First, annualized values of *IR* are provided by computing the total amount of fish consumed each year and dividing this total by 365 days per year. The basis for these values is labeled "Annualized IR" in Table 5-10 with *EF* set equal to a constant value of 365 days per year for all studies. Second, the normalized number of meals per year (*EF*) are provided by computing the total amount of fish consumed each year and dividing this total by an average meal size of 227 grams per meal (g/meal). The basis for these values is labeled "Normalized Meals per Year" in Table 5-10 with *IR* set equal to a constant value of 227 g/meal for all studies. Based on this comparison, the highest intakes are for West *et al.* (1993), while West *et al*. (1989) and Fiore *et al.* (1989) have almost identical intakes.

Ingestion Rate and Exposure Frequency for High-intake Fish Consumers. High-intake fish consumers are individuals who consume greater quantities of fish than typical recreational anglers. Three such populations are considered here:

- Low-income minorities,
- Native Americans, and
- Hmong or Hmong/Laotians.

The number of low-income minority anglers is not known, but the 1993 West *et al.* study identified about 2.8 percent of the angling population surveyed as low-income minority. The low-income minority population was about 37 percent of the total number of minority anglers in the 1993 West *et al.* study. If the general angling population is 136,000 individuals based on the number of fishing licenses issued (WDNR, 1999d) then the number of low-income minority anglers is about 3,800 individuals. The two Native American tribes residing closest to the Lower Fox River and Green Bay are the Oneida and Menominee. The number of anglers in these tribes is not known at this time, although the Oneida currently have about 6,800 people living on the reservation in Brown or Outagamie counties or the Milwaukee area, and about 1,750 people living elsewhere in Wisconsin. Hutchison and Kraft (1994) indicate that the population of Hmong in Green Bay-Brown County was 2,000 individuals in the 1990 census. Hutchison and Kraft (1994) report that about 58 percent of these households have at least one family member who fishes. If there are similar numbers of people in angling and non-angling households, then approximately 1,200 Hmong live in households where at least one person fishes.

Table 5-11 summarizes intake assumptions for the populations of high-intake fish consumers. As with the recreational angler, values for the amount of fish consumed per meal (*IR*) and the number of meals per year (*EF*) varied depending on the study used as the basis. West *et al.* (1993) provides consumption data for low-income, minority anglers. The intake rates developed in this study are daily intakes averaged over a year. Based on the results of the study, *IR* is 110 g/day for the RME scenario and 43 g/day for the CTE scenario, and *EF* is 365 days/yr. The RME intake rate of 110 g/day for the high-intake fish consumer is only slightly greater than the RME intake rate of 78 g/day for the recreational angler.

There are no sport fish consumption data currently available for the two tribes closest to the Lower Fox River and Green Bay. Peterson *et al*. (1994) evaluated the fish consumption patterns of the Chippewa tribe in northern Wisconsin. Their data indicate that these individuals consume about 50 percent more fish (sport fish and commercial fish) than the general Wisconsin anglers surveyed by Fiore *et al*. (1989). The *Exposure Factors Handbook* (EPA, 1997b) states that "several studies show that intake rates of recreationally caught fish among Native Americans with state fish licenses (West *et al*., 1989; Ebert *et al*., 1993) are somewhat higher (50 to 100 percent) than intake rates among other anglers." While Peterson *et al*. (1994) did not specifically identify intake rates for sport-caught fish, their result of 50 percent higher consumption of fish overall was applied to the Fiore *et al.* (1989) data. Thus, *IR* was assigned the value of 227 g/day based on the follow-up to the Fiore *et al*. (1989) study, and *EF* was assigned a value of 89 days per year for the RME scenario and 27 days/yr for the CTE scenario.

The Menominee tribe reviewed these assumptions and indicated that the Menominee angling patterns are similar to the Chippewa. They indicated that the Menominee have a high period of fishing in the winter (ice fishing) in addition to a high period of fishing in the spring. Thus, the estimates provided in Table 5-11 could underestimate fish consumption rates for the Menominee.

There are two studies of sport fish consumption patterns for Hmong or Hmong and Laotians living in Green Bay. The first study (Hutchison and Kraft, 1994) surveyed overall sport fish consumption patterns for Hmong. The second study (Hutchison, 1999) examined consumption of fish from the Lower Fox River between the De Pere dam and the mouth of the river at Green Bay for Hmong and Laotians. Hutchison (1994) also performed another study of angling habits which focused on Hmong living in Sheboygan, Wisconsin. The first study (Hutchison and Kraft, 1994), which examined the consumption of all sport fish, generated an average frequency of 34 meals/yr and a 95th percentile of 130 meals/yr (based on 2.5 meals per week; see Table 5-12). The second study (Hutchison, 1999), which examined consumption of fish caught from the Lower Fox River from De Pere to the river mouth in Green Bay, generated an average of 12 meals/yr and a 95th percentile of 52 meals/yr (see Table 5-13). In the first study (Hutchison and Kraft, 1994), it was noted that the Lower Fox River was the preferred fishing location for only 17 percent of anglers surveyed, so the first study probably overestimates fish consumption from the Lower Fox River and Green Bay within the Hmong angling population. In the second study (Hutchison, 1999), it was noted that anglers who fish in the Lower Fox River from De Pere to the river mouth may also fish in Little Lake Butte des Morts, which is also part of the Lower Fox River, so the second study may underestimate fish consumption from the Lower Fox River and Green Bay. The study by Hutchison (1999) also asked respondents if they were aware of the fish advisories on the Lower Fox River and whether these advisories had caused them to alter their angling behavior. Many respondents indicated that they were aware of the advisories and that they ate less fish from the Lower Fox River as a result. Thus, the estimates developed by Hutchison (1999) underestimate the amount of fish that might be consumed if there were no fish advisories.

The results of both studies are presented in Table 5-11. For the first study (Hutchison and Kraft, 1994), *EF* is set to 130 days/yr for the RME scenario and 34 days/yr for the CTE scenario. For the second study (Hutchison, 1999), *EF* is set to 52 days/yr for the RME scenario and 12 days/yr for the CTE scenario. The size of the meal was not quantified in either study, but Hutchison (1994) did estimate meal size in his study of Hmong fish habits in Sheboygan, Wisconsin. Table 5-14 summarizes the results of showing anglers 0.33- and 0.5-pound servings of raw fillets and asking the anglers how much fish they ate at each meal. The most frequent response was "other," but for the respondents who identified 0.33, 0.5, or 1 pound as the meal size, the average is 0.52 pounds, or about 8 ounces (227 grams). Thus, the amount of fish consumed per meal (*IR*) was set to 227 g/day.

To allow intake assumptions to be compared directly, values of *IR* and *EF* are provided in Table 5-11 for each study using common bases, as discussed previously for recreational anglers. Annualized values of *IR* ("Annualized IR") and values of *EF* based on a normalized quantity of fish consumed per meal ("Normalized Meals per Year") are provided in Table 5-11. Based on this comparison, the highest intake is for the low-income minority angler, followed by the Hmong angler based on Hutchison and Kraft (1994), then the Native American angler and, finally, the Hmong/Laotian angler based on Hutchison (1999).

Reduction Factors. This section discusses the reduction factors (*RF*) used for fish. The reduction factor for fish (RF_{fish}) depends on how the fish is sampled and analyzed to generate a fish concentration (*Cfish*) and the meal size used in the evaluation. In this analysis, *Cfish* is the concentration of COPCs in raw fish, generally skin-on fillet. Trimming will reduce the mass of fish consumed and will reduce the concentration if fatty parts with higher concentrations are trimmed (Anderson *et al.,* 1993; Zabik *et al.,* 1993; Stachiw *et al.,* 1988; Zabik *et al.,* 1982). Cooking will also reduce the mass of fish, principally through water loss, but also through volatilization of COPCs (Anderson *et al.,* 1993; Zabik *et al.,* 1993; Stachiw *et al.,* 1988; Zabik *et al.,* 1982). In many cases, the overall tissue concentrations after trimming and cooking are similar to the concentrations in the raw, uncooked fish, but the mass of fish has been reduced, so the total mass of COPCs in the cooked fish is less than in the uncooked fish. In other cases, the tissue concentrations of COPCs after trimming and cooking are less than the concentrations in the raw, uncooked fish. In these cases the total mass of COPCs in the fish portion has been reduced by concentration reduction as well as reduction in the mass of fish (Anderson *et al.*, 1993).

The meal size estimated by West *et al.* (1989, 1993), Fiore *et al.* (1989) and Hutchison (1994) are all about 227 grams (or 8 ounces) on average. The meal size for West *et al.* (1989, 1993) is for cooked fish, whereas the meal size for Fiore *et al.* (1989) and Hutchison (1994) are for uncooked portions. Given the qualitative nature of estimating meal size by respondents to the various surveys, reduction factors have been determined for an uncooked portion. This approach is consistent with the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993).

In the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory*, Anderson *et al.* (1993) review the effects of trimming fat, skin removal, and cooking on the reduction of chemical concentrations in fish. For PCBs, DDT, mirex, and DDE, they report reductions from trimming ranging from 43 to 90 percent and recommend a value of 20 percent for reduction due to trimming. For PCBs, DDT, DDE, dieldrin, and mirex, they report reductions of 0 to 80 percent due to cooking, with most values between 20 and 70 percent. They recommend using 30 percent as the reduction factor for cooking. Since skin accumulates lipophilic chemicals and most of the fillet data available for the Lower Fox River and Green Bay are from samples with the skin on, a reduction factor of 50 percent (20 percent for trimming and 30 percent for cooking) was used in this analysis for organic chemicals. In addition, West *et al.* (1993) reported that 43.9 percent of anglers did not trim the fat, and 36.5 percent did not remove the skin. Since mercury is not lipophilic, no reduction by trimming and cooking has been applied. Similarly, no reduction has been applied for arsenic or lead.

Exposure Duration. This section discusses the basis for the values used for the exposure duration (*ED*) for anglers and hunters. Appendix B1 presents a calculation of the time the potentially exposed population of anglers is expected to catch fish in the Lower Fox River and Green Bay. The fundamental assumption used in this analysis presented in Appendix B1 is that the number of years the angler or hunter fishes or hunts is equal to the number of years the angler or hunter lives in the Lower Fox River and Green Bay region. The calculation presented in Appendix B1 recognizes that different anglers and hunters will spend different times in the area and, therefore, generate a probability distribution for *ED*. This probability distribution depends on the age of a receptor (person) when that individual moves into the region, and the percent of times a move is within the region (as opposed to moving out of the region). Depending on the assumptions made for these two parameters, the mean of the probability distribution of *ED* ranges between 18 years and 33 years. The 95 percent value ranges between 25 and 75 years.

ED values of 30 years for the CTE scenario and 50 years for the RME scenario were established based on professional judgment prior to developing the probabilistic analysis described in Appendix B1. These CTE and RME values are, however, consistent with the probability distributions, so these values are retained as the CTE and RME values for this analysis.

Recreational Anglers

Recreational anglers are individuals who fish in the Lower Fox River and Green Bay for recreational purposes. The Lower Fox River and Green Bay support a variety of sport and non-sport fish as discussed previously. Recreational anglers are exposed to chemicals in the river and bay through the ingestion of fish. These individuals are also exposed to chemicals in the river and bay through incidental ingestion of water during fishing, dermal contact with water during fishing, and inhalation of chemicals volatilized into the air from surface water. The exposures via water ingestion and dermal contact are likely to be sporadic, since recreational anglers are not intentionally entering the water.

For the recreational angler, intake assumptions are provided for an RME scenario and a CTE scenario. The intake assumptions for the RME scenario are provided in Table 5-15, and the intake assumptions for the CTE scenario are provided in Table 5-16. The intake assumptions for the RME scenario are discussed first. After all the intake assumptions for the RME scenario are presented, the intake assumptions for the CTE scenario that differ from those in the RME scenario are discussed.

The body weight (*BW*) for the recreational angler was set to 71.8 kg, for the average adult female and male body weight (EPA, 1997b). The exposure frequency (*EF*) is pathway-specific.

The exposure duration (*ED*) is discussed in the previous subsection.

The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, or 27,375 days (EPA, 1997b). The *AT* for evaluating non-carcinogenic effects is the exposure duration (50 years) multiplied by 365 days/yr (EPA, 1989c), or 18,250 days.

For the fish ingestion pathway, the ingestion rate (*IR*) was based on the West *et al.* (1989, 1993) studies. For the RME scenario, the average of the West *et al.* (1989, 1993) values in Table 5-10, 59 g/day, was used for *IR* and *EF* was set to

365 days/yr. The reduction factor (*RF*) to account for chemical loss due to trimming and cooking is a chemical-specific value and is discussed in Section 5.5. The absorption factors (*ABS*) for ingestion of fish are assumed to be 100 percent for all chemicals.

For the incidental surface water ingestion pathway, the RME value for *EF* is 95 days/yr, which assumes the number of fishing events equals the number of fish meals per year for this receptor. The daily incidental ingestion rate (*IR*) for surface water was 20 milliliters per day (ml/day), which is based on the approximate amount for one mouthful of water. It was conservatively assumed that incidental ingestion of water would occur once every 10 fishing trips, so the fraction ingested (*FI*) was assumed to be 10 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the RME value for *EF* is 95 days/yr, the same as for incidental ingestion of water. The exposure time (*ET*) for contact with surface water is assumed to be 15 minutes throughout the day, or 0.25 hr/day. The total body surface area (*TBS*) used for the RME exposure scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). It was assumed that hands and forearms were the exposed body parts that would come in contact with water. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997a), and an exposed skin area (*SA*) of 1,125 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, it was assumed the recreational angler could potentially inhale constituents each day they fish, so the value for *EF* is 95 days/yr. Exposure time (*ET*) was set at 6 hrs/day, based on professional judgment. The inhalation rate (*IR*) for an angler was assumed to be 1.0 m^3/hr, which is the EPA's recommended value for adults involved in light activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Table 5-16 provides a list of specific intake assumptions for the recreational angler to evaluate a CTE scenario. Many of the exposure assumptions are similar to the RME scenario; however, the following values are different. The exposure duration (*ED*) was set to 30 years, the assumed average time an individual lives in the Lower Fox River and Green Bay area. As a result, the non-carcinogenic averaging time (*AT*) is equal to 10,950 days. For the fish ingestion pathway, the ingestion rate (*IR*) for the CTE scenario is 15 g/day, which is the average of the CTE values for West *et al.* (1989, 1993) in Table 5-10. Using the assumption that the number of fishing events equals the number of fish meals, the *EF* for each surface water pathway was changed to 24 days/yr. The total body surface area was set to 18,150 cm^2, which represents the average of the mean values for adult men and women (EPA, 1997b). Subsequently, the surface area exposed to water (5.15 percent of the total) is equal to 935 cm^2.

High-intake Fish Consumers

High-intake fish consumers are individuals who would not be able to meet their daily nutritional requirements if they could not supplement their diet with sport-caught fish. Thus, the frequency with which a high-intake fish consumer will consume potentially contaminated fish is significantly higher for the high-intake fish consumer, as opposed to the recreational angler. The exposure pathways for the high-intake fish consumer are the same as those for the recreational angler.

For the high-intake fish consumer, intake assumptions are provided for an RME scenario and a CTE scenario. The intake assumptions for the RME scenario are provided in Table 5-17, and the intake assumptions for the CTE scenario are provided in Table 5-18. The intake assumptions for the RME scenario are discussed first. After all the intake assumptions for the RME scenario are presented, the intake assumptions for the CTE scenario that differ from those in the RME scenario are discussed.

The body weight (*BW*) for the high-intake fish consumer was set to 71.8 kg (EPA, 1997b). The exposure frequency (*EF*) is pathway-specific. For the RME exposure scenario, the exposure duration (*ED*) was set to 50 years, the same as for the recreational angler.

For the fish ingestion pathway, the ingestion rate (*IR*) and exposure frequency were determined from the data for Hutchison and Kraft (1994) in Table 5-11. The value of *IR* is 227 g/day and *EF* is 130 days per year. The reduction factor (*RF*) to account for chemical loss due to trimming and cooking is a chemical-specific value and is discussed in Section 5.5. The absorption factors (*ABS*) for ingestion of fish are assumed to be 100 percent for all chemicals.

For the incidental surface water ingestion pathway, the value for *EF* is 130 days/yr, based on the assumption that the number of fishing events is equal to the number of fish meals per year for this receptor. The daily incidental ingestion rate (*IR*) for surface water was 20 ml/day, which is based on the approximate amount for one mouthful of water. It was assumed that incidental ingestion of water would occur once every 10 fishing trips, so the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the *EF* is 130 days/yr, the same as for incidental ingestion of water. The exposure time (*ET*) for contact with surface water is assumed to be 30 minutes throughout the day, or 0.5 hr/day. The total body surface area (*TBS*) used for the RME exposure scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997a). It was assumed that hands were the exposed body parts that would come in contact with water. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,125 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, it was assumed the high-intake fish consumer could potentially inhale constituents each day they fish, so the value for *EF* is 130 days/yr. Exposure time (*ET*) was set at 4 hrs/day, based on professional judgment. The inhalation rate (*IR*) for an angler was assumed to be 1.0 m^3/hr, which is the EPA's recommended value for adults involved in light activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Table 5-18 provides a list of specific intake assumptions for the high-intake fish consumer to evaluate the CTE scenario. Many of the exposure assumptions are similar to the RME scenario; however, the following values are different. The exposure duration (*ED*) was set to 30 years, the same value used for the recreational angler for the CTE scenario. As a result, the non-carcinogenic averaging time (*AT*) is equal to 10,950 days. For the fish ingestion pathway, the exposure frequency (*EF*) is 34 days/yr based on data from Hutchison and Kraft (1994) presented in Table 5-11. Using the assumption that the number of fishing events equals the number of fish meals, the *EF* for each surface water pathway was changed to 34 days/yr. The total body surface area was set to 18,150 cm^2, which represents the average of the mean values for adult men and women (EPA, 1997b). Subsequently, the exposed surface area (5.15 percent of the total) is equal to 935 cm^2.

Hunters

Hunters are individuals who hunt waterfowl in the Lower Fox River and Green Bay. These individuals may be exposed to chemicals through ingestion of waterfowl. Like anglers, these individuals may also be exposed to constituents in the river and bay through inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water contacted during hunting, and dermal contact with water contacted during hunting. The exposures via water ingestion and dermal contact are likely to be low for this receptor, since hunters may not contact the water at all.

For the hunter, intake assumptions are provided for an RME scenario and a CTE scenario. The intake assumptions for the RME scenario are provided in Table 5-19, and the intake assumptions for the CTE scenario are provided in Table 5-20. The intake assumptions for the RME scenario are discussed first. After all the intake assumptions for the RME scenario are presented, the intake assumptions for the CTE scenario which differ from those in the RME scenario are discussed.

The body weight (*BW*) for the hunter was set to 71.8 kg (EPA, 1997b). The exposure frequency (*EF*) is pathway-specific. The exposure duration (*ED*) is 50 years, based on the same assumptions of population mobility that were used for the recreational angler. The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is the exposure duration multiplied by 365 days/yr (EPA, 1989c), or 18,250 days.

For the waterfowl ingestion pathway, the value for *EF* is the number of meals per year and was set at 12 meals per year for the RME scenario, based on information presented by Amundson (1984). In this study, Illinois goose hunters were surveyed to establish eating habits and consumption rates. The group of hunters was selected on the basis of having claimed to shoot an average of five or more geese per year. The survey included questions regarding the consumption frequency of the hunters and their family members. The results of the survey indicated an average consumption of approximately three geese per year, with a maximum of about six geese per year. Because the Amundson (1984) study only considered Canada geese, and not other commonly eaten waterfowl such as duck, these values have been doubled for the RME and CTE scenarios in this assessment (i.e., values of 12 meals/yr and 6 meals/yr are incorporated). The representative meal size (*IR*) was set to 110 g/meal (reasonable maximum from Pao *et al*., 1982). This is likely to be the meal size after cooking.

The reduction factor (*RF*) to account for chemical loss due to cooking is set equal to 100 percent based on information presented by Amundson (1984). One goal of this study was to determine the influence of cooking on raw residue levels in edible portions of Canada geese. Amundson sampled raw breast skin and raw breast meat for dieldrin, heptachlor, DDE, and Aroclor 1254. The birds were then baked for 3 hours, and the tissues were sampled again. Although concentrations of all chemicals showed reduction in skin samples after cooking, results were inconclusive for the breast meat samples. Both DDE and Aroclor 1254 showed a slight increase in concentration after cooking. Because of the inconclusive results, the reduction factor was conservatively set to 100 percent (i.e., no reduction) for all constituents. The absorption factors (*ABS*) for ingestion of waterfowl are assumed to be 100 percent for all chemicals.

For the incidental surface water ingestion pathway, the *EF* for a hunter is 12 days/yr, which assumes the number of days when hunting occurs equals the number of waterfowl meals per year for this receptor. The daily incidental ingestion rate (*IR*) for surface water was 20 ml/day, which is based on the approximate amount for one mouthful of water. Exposure is assumed to occur 10 percent of the time the hunter visits the site, so the fraction ingested (*FI*) was assumed to be 10 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the *EF* is 12 days/yr, the same as for incidental ingestion of water. The exposure time (*ET*) for contact with surface water is assumed to be 15 minutes throughout the day, or 0.25 hr/day. The total body surface area (*TBS*) used for the RME scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). It was assumed that only the hands of a hunter would be exposed to surface water. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,125 cm^2. The fraction of the surface water contacted at the site (*FC*) was assumed to be 100 percent, which is conservative and health protective. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, it was assumed the hunter could potentially inhale constituents each day they hunted, so the value for *EF* is 12 days/yr. Exposure time (*ET*) was set at 8 hrs/day, based on professional judgment. The inhalation rate (*IR*) for a hunter was assumed to be 1.0 m^3/hr, which is the EPA's recommended value for adults involved in light activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Table 5-20 provides a list of specific intake assumptions for the hunter to evaluate the CTE scenario. Many of the exposure assumptions are similar to the RME scenario; however, the following values are different. The exposure duration (*ED*) was set to 30 years, the assumed average time an individual lives in the Lower Fox River and Green Bay area. As a result, the non-carcinogenic averaging time (*AT*) is equal to 10,950 days. For the waterfowl ingestion pathway, the exposure frequency (*EF*) was equal to 6 meals/yr (Amundson, 1984). Using the assumption that the number of hunting events equals the number of waterfowl meals, the *EF* values for surface water pathways were changed to 6 days/yr. The total body surface area was set to 18,150 cm^2, which represents the average of the mean values for adult men and women (EPA, 1997b). Subsequently, the surface area exposed to water (5.15 percent of the total) is equal to 935 cm^2.

Drinking Water Users

Drinking water users are individuals that use water from the Lower Fox River or Green Bay as either a primary or secondary source of drinking water. Potential exposures associated with direct use of water include ingestion; dermal contact during bathing, cooking, and other household uses of water; and inhalation of chemicals volatilized into the air during showering and other uses.

Table 5-21 provides a list of the specific intake assumptions used for the drinking water users. Specific assumptions have been made only for the RME scenario. In addition, the assumptions for this receptor have been divided into two age groups, a young child 1 to 6 years of age and an older child and adult who is 7 years or older.

The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime. To be consistent with EPA conventions for evaluating drinking water exposure, the duration of time spent in a residence is used to specify the total exposure period. For the RME scenario, the upper-bound value of 30 years in a residence (EPA, 1997b) has been used, with the first 6 years as a young child and the remaining 24 years as an older child and adult. The *AT* for evaluating non-carcinogenic effects is 365 days/yr over 30 years.

The exposure frequency (*EF*) is 350 days/yr, the value presented in EPA (1991a) for a resident. The exposure duration (*ED*) and body weight (*BW*) are specific to the age group. For the time period as a young child, the exposure duration (*ED*) is 6 years; the *ED* for the older child and adult is 24 years. The body weight for a child is 16.6 kg (based on the average values for boys and girls age 1 to 6; EPA, 1997b) and for an adult is 71.8 kg (EPA, 1997b).

For the water ingestion pathway, the daily ingestion rate (*IR*) was 1.5 L/day for the young child and 2.3 L/day for the older child and adult. These are the upper-percentile values presented in EPA (1997b) for a child age 3 to 5 and an adult, respectively. The absorption factors (*ABS*) for ingestion of water are assumed to be 100 percent for all chemicals.

For the dermal contact with water pathway, the fraction of the body assumed to be exposed (*FBE*) was conservatively assumed to be 100 percent, since contact with water would occur during bathing or showering. For young children of ages 1 through 6 years, the total body surface area (*TBS*) was set to the average of values for male and female children between 5 and 6 years of age in EPA (1997b), which provides values of *TBS* for different percentiles. Values of *TBS* between the 50^{th} and 75^{th} percentiles for male and female children were averaged to yield a value of 8,105 cm^2 for young children. The *TBS* for an older child or adult (ages 7 through 31) was the average of the upper-bound values for adult men and women presented in EPA (1997b) of 21,850 cm^2. Specifying *FBE* as 100 percent results in exposed surface areas (*SA*) of 8,105 cm^2 and 21,850 cm^2 for the young child and older child/adult, respectively.

Exposure time (*ET*) for the young child is 20 minutes, or 0.33 hr/day, the average time spent in the bath (EPA, 1997b). For the older child and adult, *ET* is estimated to be 15 minutes, or 0.25 hr/day. This is the average time spent bathing (20 minutes) or showering (10 minutes) each day (EPA, 1997b). Presumably, all the household water is from the site, so the fraction contacted (*FC*) equals 100 percent. The dermal permeability constants (*PC*) are chemical-specific were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, an inhalation rate (*IR*) of 1.0 m^3/hr was used to evaluate exposure for both the young child and older child/adult. These values are based on the inhalation rates for an adult or child engaged in light activities (EPA, 1997b). The exposure times (*ET*) used were the same as those for the dermal contact pathway, 0.33 hr/day and 0.25 hr/day for the young child and older child/adult, respectively. The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Local Residents

Local residents are individuals who live next to the Lower Fox River or Green Bay. There are homes located along the water throughout the length of the Lower Fox River, except in downtown Green Bay. Potential exposures associated with living next to the river include inhalation of chemicals volatilized into the air from the surface water.

Table 5-22 provides a list of the specific intake assumptions used for the local residents to evaluate the RME scenario. Separate assumptions have not been made for RME and CTE scenarios, as the pathway is restricted to volatile inhalation only. As with the drinking water user, intake assumptions have been developed for two age groups, the younger child aged 1 to 6 years and the older child aged 7 years or older.

The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime. The duration of time spent in a residence is used to specify the total exposure period. Since this individual is assumed to live next to the river or Green Bay, if they move it is unlikely to be to another house as close to the river or Green Bay. Thus, the time spent at one residence was used to specify the exposure period, so the averaging time (*AT*) for evaluating non-carcinogenic effects is 365 days/yr over 30 years.

The exposure frequency (*EF*) is 350 days/yr, the value presented in EPA (1991a) for a resident. The exposure duration (*ED*) and body weight (*BW*) are receptor-specific. For the time period as a young child, the exposure duration (*ED*) is 6 years; the *ED* for the older child and adult is 24 years (EPA, 1991a). The body weight for a child is 16.6 kg (based on the average values for boys and girls age 1 to 6; EPA, 1997b) and for an adult is 71.8 kg (EPA, 1997b).

For the volatile inhalation pathway, an inhalation rate (*IR*) of 0.42 m^3/hr over a 24-hour day (*ET*) was used to evaluate exposure for the young child. An *IR* of 0.55 m^3/hr over a 24-hour day was used for the older child/adult. These values are based on the daily rates of 10 cubic meters per day (m^3/day) and 13.3 m^3/day presented in EPA (1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Recreational Water Users

The recreational water user has been divided into two receptors for this analysis, an adult who swims in the river or bay and an older child who wades along the shore of the river or bay. Potential exposures associated with swimming and wading include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water, dermal contact with water, incidental ingestion of sediment, and dermal contact with sediment or sediment pore water.

Table 5-23 provides a list of the specific intake assumptions used for the swimmer, who is assumed to be an adult. The body weight (*BW*) was set to 71.8 kg (EPA, 1997b). The exposure frequency of 18 days/yr was based on a conservative estimate of swimming once per week for the warmest 4 months of the year. The exposure duration (*ED*) was set at 30 years, which is the default exposure duration for a resident (EPA, 1991a). This value of *ED* is the same as that used for the CTE anglers and hunter based on population mobility data. The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is *ED* multiplied by 365 days/yr, or 10,950 days.

For the incidental surface water ingestion pathway, the incidental ingestion rate (*IR*) was 20 ml/day, which is based on the approximate amount for one mouthful of water. All of this exposure is assumed to occur at the site, so the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the exposure time (*ET*) for swimming was set to 1 hr/day, the average time for swimming per event (EPA, 1997b). The total body surface area (*TBS*) was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). The fraction of the body exposed (*FBE*) was assumed to be 100 percent, since this receptor would be completely submerged while swimming. Specifying *FBE* as 100 percent results in an exposed surface area (*SA*) of 21,850 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, the exposure time (*ET*) is assumed to be 1 hr/day, the same as the time spent swimming. The inhalation rate (*IR*) for a swimmer was assumed to be 3.2 m^3/hr, which is the EPA's recommended value for an adult engaged in heavy activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

The daily incidental ingestion rate (*IR*) for sediment was 5 milligrams per day (mg/day), which is one-tenth the daily soil ingestion rate presented for an adult in EPA (1997b). It is highly unlikely that significant sediment ingestion would occur, and in the absence of guidance on this pathway, the above rate was based on professional judgment. All of this exposure is assumed to occur at the site during the event; thus, the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) are chemical-specific and are presented in Table 5-8.

For the dermal contact with sediment pathway, it was assumed that the feet were the only exposed body parts that would come in contact with sediment. This corresponds to a fraction of the body exposed (*FBE*) as 6.75 percent (the average value for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,475 cm^2. The sediment adherence factor (*AF*) of 1.0 mg/cm^2 was based on the upper value for soil contact from EPA's Dermal Guidance (1992a). The dermal absorption factors (*ABS*) are chemical-specific and are presented in Table 5-9. It should be noted that the absorption factors for direct contact with sediment are based on contact with soil and are typically based on longer term absorption studies (such as 24 hours or longer [EPA, 1992a]). The swimmer probably spends little time standing in the sediment, since their primary activity is swimming, not wading. If it is conservatively estimated that the swimmer spends 15 minutes standing in sediments (one-fourth of the total time spent in the water), then this is considerably shorter than the duration of a typical dermal absorption experiment. For example, EPA (1992a) estimated 0.6 to 6 percent absorption of PCBs from soil after 24 hours of contact. Since 15 minutes (or 0.25 hour) is about 1 percent of 24 hours, actual absorption is expected to be less than that observed in the experimental studies. To account for this, the parameter *FC* (fraction of daily contact occurring at the site) was set to 5 percent, which is five times greater than 0.25 hour per 24 hours or 1 percent.

As an alternative to evaluating sediments with the above methodology, the analysis for the swimmer includes the option to evaluate dermal contact with sediment pore water instead of contact with actual sediments. The exposure factors for the dermal contact with sediment pore water are similar to those used for the dermal contact with surface water pathway. The exposure time (*ET*) was equal to 15 minutes, or 0.25 hr/day. As with sediment contact, it was assumed that the feet were the only body parts that could be exposed to sediment pore water. Therefore, the *FBE* of 6.75 percent and *SA* of 1,475 cm^2 identified above were incorporated into this intake calculation. The *PC* values were presented in Table 5-6.

Table 5-24 provides a list of the specific intake assumptions used for the wader, who is assumed to be an older child between the ages of 9 and 18. The body weight (*BW*) was set to 51 kg, which is the average of the mean body weights of boys and girls from age 9 to age 18 (EPA, 1997b). The exposure frequency of 18 days/yr was based on a conservative estimate of wading once per week for the warmest 4 months of the year. The exposure duration (*ED*) was set at 10 years, based on the age range of the older child. The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is *ED* multiplied by 365 days/yr, or 3,650 days.

For the incidental surface water ingestion pathway, the incidental ingestion rate (*IR*) was 20 ml/day, which is based on the approximate amount for one mouthful of water. Since ingestion of surface water is unlikely while wading, exposure is assumed to occur during only 10 percent of the visits to the site; therefore, the fraction of exposure time ingestion occurs (*FI*) was assumed to be 10 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the exposure time (*ET*) for wading was set to 0.5 hour per day, based on professional judgment. The total body surface area (*TBS*) was 14,400 cm^2 (the average of the 50^{th} percentile values for girls and boys between ages 9 and 18; EPA, 1997b). The fraction of the body exposed (*FBE*) was 22.9 percent, which corresponds to the feet and lower legs of older children. Specifying *FBE* as 22.9 percent results in an exposed surface area (*SA*) of 3,298 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, the exposure time (*ET*) is assumed to be 0.5 hr/day, the same as the time spent wading. The inhalation rate (*IR*) for an older child while wading was assumed to be 1.2 m^3/hr, which is the EPA's recommended value for children engaged in moderate activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

The daily incidental ingestion rate (*IR*) for sediment was 5 mg/day, which is one-tenth the daily soil ingestion rate presented for an older child in EPA (1997b). It is highly unlikely that significant sediment ingestion would occur, and in the absence of guidance on this pathway, the above rate was based on professional judgment. All of this exposure is assumed to occur at the site during the event; thus, the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) are chemical-specific and are presented in Table 5-8.

For the dermal contact with sediment pathway, it was assumed that the feet were the only exposed body parts that would come in contact with sediment. This corresponds to a fraction of the body exposed (*FBE*) as 7.37 percent (the average value for boys and girls between the ages of 9 and 18; EPA, 1997b), and an exposed skin area (*SA*) of 1,061 cm^2. The sediment adherence factor (*AF*) of 1.0 mg/cm^2 was based on the upper value for soil contact from EPA's Dermal Guidance (1992a). The dermal absorption factors (*ABS*) are chemical-specific and are presented in Table 5-9. It should be noted that the absorption factors for direct contact with sediment are based on contact with soil and are typically based on longer-term absorption studies (such as 24 hours or longer [EPA, 1992a]). The wader is assumed to spend 30 minutes in contact with sediments, which, as indicated above, is considerably shorter than the duration of a typical dermal absorption experiment. Since 30 minutes (or 0.5 hour) is about 2 percent of 24 hours, actual absorption is expected to be less than that observed in the experimental studies. To account for this, the parameter *FC* (fraction of daily contact occurring at the site) was set to 10 percent, which is five times greater than 0.5 hour per 24 hours or 2 percent.

As an alternative to evaluating sediments with the above methodology, the analysis for the wader includes the option to evaluate dermal contact with sediment pore water instead of contact with actual sediments. The exposure factors for the dermal contact with sediment pore water are similar to those used for the dermal contact with surface water pathway. The exposure time (*ET*) was equal to 30 minutes, or 0.5 hr/day. As with sediment contact, it was assumed that the feet were the only body parts that could be exposed to sediment pore water. Therefore, the *FBE* of 7.37 percent and *SA* of 1,061 cm^2 identified above were incorporated into this intake calculation. The *PC* values were presented in Table 5-6.

Marine Construction Workers

Marine construction workers are individuals engaged in dredging or construction activities within the river or bay. Potential exposures associated with construction activities or navigational dredging include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of and dermal exposure to water contacted during work activities, and incidental ingestion of and dermal exposure to sediment contacted during work activities.

Table 5-25 provides a list of the specific intake assumptions used for the marine construction workers. Specific assumptions have been made only for the RME scenario. The body weight (*BW*) was set to 71.8 kg (EPA, 1997b). The exposure frequency (*EF*) of 24 days/yr was based on an estimated dredging frequency of 2 days per month. The exposure duration (*ED*) was set at 25 years, the value specified for a worker in EPA (1991a). The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is *ED* multiplied by 365 days/yr, or 9,125 days (EPA, 1989c).

For the incidental surface water ingestion pathway, the incidental ingestion rate (*IR*) was 20 ml/day, which is based on the approximate amount for one mouthful of water. All of this exposure is assumed to occur at the site, so the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the exposure time (*ET*) for the worker was set to 30 minutes, or 0.5 hr/day, based on an assumption that exposure might occur for a total of 0.5 hour during the workday. The total body surface area (*TBS*) used for the RME scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). It was assumed that hands and forearms were the exposed body parts that would come in contact with water. This corresponds to a fraction of the body exposed (*FBE*) as 11.6 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 2,535 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to the equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, the exposure time (*ET*) is the full work day, or 8 hrs/day. The inhalation rate (*IR*) for the RME scenario was assumed to be 1.5 m^3/hr, which is the EPA's recommended value for an outdoor worker engaged in moderate activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

The daily incidental ingestion rate (*IR*) for sediment was 25 mg/day, which is one-half the daily soil ingestion rate presented for an adult in EPA (1997b). It is not likely that sediment ingestion would occur, and in the absence of guidance on this pathway, the above rate was selected based on professional judgment. All of this exposure is assumed to occur with site sediments; thus, the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) are chemical-specific and are presented in Table 5-8.

For the dermal contact with sediment pathway, it was assumed that the hands were the only exposed body part that would come in contact with sediment. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,125 cm^2. The sediment adherence factor (*AF*) of 1.0 mg/cm^2 was based on the upper value for soil contact from EPA's Dermal Guidance (1992a). The fraction of the sediment contacted from the site (*FC*) was assumed to be 100 percent, which is conservative and health protective. The dermal absorption factors (*ABS*) are chemical-specific and are presented in Table 5-9. As previously noted, these absorption factors are based on direct contact with soil over an extended period of time, and are likely to significantly overestimate actual intake for this receptor.

5.5 Exposure Point Concentrations

Exposure point concentrations are representative concentrations of COPCs in media (e.g., sediment, surface water, fish) that a receptor is assumed to contact. Exposure point concentrations are required for the following exposure media:

- Fish,
- Waterfowl,
- Water via ingestion,
- Water via dermal contact,
- Sediment,
- Sediment pore water,

- Indoor air during bath,
- Indoor air during shower, and
- Outdoor air.

These exposure point concentrations are determined either directly from measurements of the applicable exposure medium or through the application of mathematical models that translate measured concentrations in source media to exposure point concentrations in exposure media. In theory, the concentrations in source media can vary with time, so the appropriate concentration for estimating exposure to a particular receptor is an average concentration over the exposure period. Thus, the time-averaged source concentrations and resulting exposure point concentrations can be different for different receptors for the same exposure medium. However, the change in source concentration with time is very difficult to assess. For this analysis, all source concentrations are treated as being constant in time. Therefore, an exposure point concentration can be estimated for each exposure medium and used for multiple receptors. It should be noted that the Lower Fox River and Green Bay mass balance modeling is used to evaluate the effect of time on the concentration of PCBs in sediment and, through bioaccumulation, fish. This evaluation is presented in the alternative-specific risk assessment in the Feasibility Study.

5.5.1 Determination of Exposure Point Concentrations

The exposure point concentrations for each exposure medium were determined as follows. For fish, the measured fish concentration ($Cfish_{meas}$) was used as the source concentration and was multiplied by a reduction factor (RF_{fish}) to yield the exposure point concentration in fish ($Cfish_{EPC}$).

$$Cfish_{EPC} = RF_{fish} \cdot Cfish_{meas}$$

The reduction factors for fish (RF_{fish}) were discussed previously.

For waterfowl, the measured concentration in waterfowl (CWF_{meas}) was multiplied by a reduction factor (RF_{WF}) to yield the exposure point concentration in waterfowl (CWF_{EPC}).

$$CWF_{EPC} = RF_{WF} \cdot CWF_{meas}$$

The reduction factors for waterfowl (RF_{WF}) were discussed previously.

For evaluating ingestion and dermal contact with water, measured concentrations in water were used. For many chemicals, both total and dissolved (filtered) concentrations were measured. For evaluating ingestion of water, the total concentration was used. For evaluating dermal contact with water, the dissolved concentration was used.

For evaluating ingestion exposure to sediment, measured concentrations in sediment were used. For evaluating dermal contact exposures to sediment, exposures were estimated either: 1) by using measured concentrations in sediment and assuming a fraction of the chemical in sediment is absorbed through the skin, or 2) by using measured sediment concentrations (C_{sed}) to estimate sediment pore water concentrations (C_{pw}) and using the sediment pore water concentration to estimate dermal absorption. The equation for estimating the sediment pore water concentration is:

$$C_{pw} = TF_{sdpw} \cdot C_{sed}$$

In this expression, TF_{sdpw} is the sediment to pore water transfer factor.

For evaluating inhalation exposures to air, measured concentrations in water were used with mathematical models of volatilization and air dispersion to estimate air concentrations. For calculating concentrations in indoor air during a bath (C_{ab}), the concentration in the bath water (C_{wb}) was multiplied by a bath water to air transfer factor (TF_{bwa}).

$$C_{ab} = TF_{bwa} \cdot C_{wb}$$

The measured dissolved concentrations were used as the concentrations in the bath water.

For calculating concentrations in indoor air during a shower (C_{as}), the concentration in the shower water (C_{ws}) was multiplied by a shower water to air transfer factor (TF_{sh}).

$$C_{as} = TF_{sh} \cdot C_{ws}$$

The measured dissolved concentrations were used as the concentrations in the shower water.

For calculating concentrations in outdoor air (C_{oa}) as a result of volatilization from surface water, the concentration in the surface water (C_{sw}) was multiplied by a surface water to air transfer factor (TF_{swoa}).

$$C_{oa} = TF_{swoa} \cdot C_{sw}$$

The measured dissolved concentrations were used as the concentrations in the surface water.

The Lower Fox River is approximately 40 miles long. To facilitate the evaluation of this water body, the data were divided into four reaches as discussed previously. The four reaches for the Lower Fox River are:

- Little Lake Butte des Morts,
- Appleton to Little Rapids,
- Little Rapids to De Pere, and
- De Pere to Green Bay.

Green Bay was evaluated as a single entity.

5.5.2 Source Concentrations

For each reach in the Lower Fox River and Green Bay, source concentrations were developed for the following media:

- Fish tissue,
- Waterfowl tissue,
- Water (total),
- Water (dissolved), and
- Sediment.

Fish Tissue

Fish tissue samples were available from a number of locations along the Lower Fox River, as well as Green Bay, Lake Winnebago, and other locations. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole. For this evaluation, the fish concentrations for the De Pere to Green Bay reach reflect fish data from De Pere to Green Bay and Zone 2 of Green Bay because these two areas have very similar habitat and fish swim freely between the two areas. The fish concentrations for Green Bay reflect fish data from zones 3A, 3B, and 4 of Green Bay.

Sample types for fish tissue consist of fillet, fillet and skin, and whole body. Sample data for fillet (skin-off and skin-on) were used to determine representative concentrations.

Data from only certain fish species were included in the evaluation. Because the risk assessment addresses fish ingestion, the species selected include those fish species that a person would reasonably eat, regardless of restrictions proposed in consumption advisories. These fish species were selected based on edible species listed in West *et al.* (1993), Anderson *et al.* (1993), and WDH/WDNR (1998) and are:

Bass (white, largemouth, smallmouth)	Pike (northern)
Bluegill	Pumpkinseed
Bowfin	Redhorse (shorthead, northern)
Bullhead (black, brown)	Rockbass
Burbot	Salmon (Chinook, Coho)
Carp	Sauger
Catfish (channel, flathead)	Smelt (rainbow)
Chub (bloater)	Splake
Cisco (lake herring)	Sucker (white, longnose)
Crappie (black)	Sunfish (green)
Drum (sheepshead)	Trout (lake, brown, brook, rainbow)
Muskellunge (musky)	Walleye
Perch (white, yellow)	Whitefish

All of the species listed above were sampled at some time and placed in the Lower Fox River and Green Bay system. The most commonly sampled species were walleye, carp, trout, and bass. Data for all edible fish species were combined and evaluated by sample type and by location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the 95 percent upper confidence limit on the arithmetic mean (95% UCL) or the maximum detected concentration, whichever is lower (EPA, 1992d); and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect, as recommended by EPA (1989c). Due to variations in detection limits, (e.g., some reported detection limits exceeded maximum detected concentrations), in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data is provided in Appendix B2.

Waterfowl Tissue

Waterfowl and other bird tissue samples were available from a number of locations in the Lower Fox River and Green Bay vicinity. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole.

Sample types for bird tissue consist of muscle, muscle and skin, whole body, and some egg and organ samples. For this risk assessment, only sample data for muscle tissue (skin-off and skin-on) were used to determine representative concentrations.

Data from only certain bird species were included in the evaluation. Because the risk assessment addresses waterfowl ingestion, the species selected include those which a person would hunt and reasonably eat. Some species, such as the common loon and the pied-billed grebe, are protected and were not included in the data set. Other bird species, such as the swallow and the gull, would not likely be eaten by a person, and were excluded as well. Confirmation of species likely to be eaten was obtained from personal communication with the Pennsylvania Game Commission (September 24, 1998). The following waterfowl and bird species included in this assessment are:

Blue-winged Teal
Bufflehead
Canada Goose
Canvasback
Common Goldeneye
Common Merganser
Gadwall
Greater Scaup
Green-winged Teal
Hooded Merganser
Lesser Scaup
Mallard
Northern Shoveler
Pintail
Red-breasted Merganser
Ring-neck Duck
Ring-neck Pheasant
Ruddy Duck
Scaup
White-winged Scoter
Wood Duck
Woodcock

Data for each of these species were combined and evaluated by location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the lower of the 95% UCL and maximum detected concentration (EPA, 1992d), and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect (EPA, 1989c). Due to variations in detection limits, in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data are provided in Appendix B2.

Surface Water

Surface water samples were available from a number of locations along the Lower Fox River and in Green Bay. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole.

Surface water data were provided for total, particulate, dissolved, and filtered samples. For the purposes of this risk assessment, dissolved and filtered samples were assumed to be similar and were grouped together. Particulate data were not used. Representative concentrations were developed for total and combined dissolved and filtered data sets in each location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the lower of the 95% UCL and maximum detected concentration (EPA, 1992d), and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect (EPA, 1989c). Due to variations in detection limits, in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data are provided in Appendix B2.

Sediment

Sediment samples were available from a number of locations along the Lower Fox River and in Green Bay. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole.

Sediment data were provided for surface and subsurface samples. For the purposes of this risk assessment, only surface sediment samples were included as a potential contact medium, although it should be noted that deeper sediments could come to the surface after storm events. Surface sediment is defined as any depth range whose shallow depth is zero (e.g., 0 to 6 inches, 0 to 2 feet). Except for total PCBs, representative concentrations were developed for surface sediments in each location using the data “as is” for each location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the lower of the 95% UCL and maximum detected concentration (EPA, 1992d), and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect (EPA, 1989c). Due to variations in detection limits, in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data are provided in Appendix B2.

For total PCBs, the representative sediment concentrations in the Lower Fox River and Green Bay were determined using vertically- and horizontally-interpolated data developed in a three-step process. First, a grid was established for each reach of the Lower Fox River and each zone of Green Bay. Second, data from the nearest sampling locations to each grid point were horizontally interpolated to provide a concentration of total PCBs at each grid point. If there was no sampling data within 1,000 feet of a grid point, no value was assigned (indicated by "ND" for "no data"). Prior to the horizontal interpolation, the data at each sampling location were vertically interpolated onto standard vertical intervals. The top interval was 0 to 10 cm. The data from this top interval was used in the risk assessment. Third, the data assigned to each grid point were used to generate a mean, a 95% UCL, and a maximum value for each reach. The representative total PCB concentration was the 95% UCL or maximum value, whichever was lower (EPA, 1992d). In performing these statistical calculations, the grid points with an "ND" assigned to them were not included. The parts of the river or bay with an "ND" are generally believed to have little or no soft sediments. Therefore, the concentrations of total PCBs in these locations are believed to be low. Thus, the effect of not including these grid points in the statistical calculations is believed to bias the numbers high, which is conservative and health protective. Additional details on the statistical evaluation of the data are provided in Appendix B2.

Results

Tables 5-26 through 5-30 present upper-bound measured concentrations for Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay, respectively. The upper-bound measured concentrations are the lower of the 95% UCL on the arithmetic mean or the maximum detected concentration. Tables 5-31 through 5-35 present average measured concentrations for Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay, respectively. The average concentrations are the arithmetic mean or the maximum detected concentration, whichever is lower.

5.5.3 Transfer Factors and Exposure Point Concentrations

Using the source concentrations described previously coupled with transfer factors, exposure point concentrations were developed for the following media:

- Shower air,
- Bath air,
- Outdoor air, and
- Sediment pore water.

The transfer factors used in this analysis are presented in Appendix B3. The resulting exposure point concentrations for each receptor in each location are provided in Appendix B4.

5.6 Dose-response Assessment

5.6.1 Overview

The purpose of the dose-response assessment is to identify the relationship between the magnitude of COPCs to which receptors may be exposed (dose) and the likelihood of an adverse health effect (response). Both non-carcinogenic (i.e., threshold) and carcinogenic (i.e., non-threshold) health effects are considered in the dose-response assessment. The information provided in the dose-response assessment is combined with the results of the exposure assessment (Sections 5.4 and 5.5) to provided an estimate of potential health risk.

Dose-response information used in this risk assessment is provided in the EPA's Integrated Risk Information System (IRIS) (EPA, 1998c) or Health Effects Assessment Summary Tables (HEAST) (EPA, 1997c). The following paragraphs describe the non-carcinogenic and carcinogenic dose-response methodologies that will be incorporated into the Lower Fox River and Green Bay risk assessment.

Non-carcinogenic Dose-response

Compounds with known or potential non-carcinogenic effects are generally assumed to have a dose below which no adverse effect is observed, or conversely, above which an effect may be seen. In laboratory experiments, this dose is known as the No Observed Adverse Effect Level (NOAEL). In the absence of a NOAEL, the Lowest Observed Adverse Effect Level (LOAEL) may be used. It is important to note that a NOAEL or LOAEL may not be an appropriate measure of effects for all chemicals or toxic endpoints, but these values are general assumptions that may be used to evaluate non-carcinogenic effects. By applying uncertainty factors to the NOAEL or the LOAEL, the EPA has developed Reference Doses (RfDs) and Reference Concentrations (RfCs) for oral and inhalation exposures to compounds with potential non-carcinogenic effects (EPA, 1998c). RfDs and RfCs are available for chronic, subchronic, and (in some cases) acute exposures. Chronic RfDs are applicable to exposures lasting 7 or more years, while subchronic RfDs are applicable to exposures lasting less than 7 years (EPA, 1989c).

Uncertainty factors account for uncertainties associated with the dose-response value, such as the effect of using an animal study to derive a human dose-response value, extrapolating from the high doses used in the laboratory experiment to the low doses typically encountered in environmental settings, and evaluating sensitive subpopulations. For compounds with potential non-carcinogenic effects, the RfD and RfC provide reasonable certainty that, if the specified exposure dose (in the case of the RfD) or exposure concentration (in the case of the RfC) is below the threshold, then no non-carcinogenic health effects are expected to occur even if daily exposure were to occur for a lifetime. RfDs are expressed in terms of milligrams of compound per kilogram of body weight per day (mg/kg-day).

Oral RfDs are provided by EPA in IRIS or HEAST. Inhalation RfDs can be calculated from RfCs. The equation for converting an RfC into an inhalation RfD depends on whether the units of the RfC are mg/m^3 or micrograms per cubic meter (μg/m^3).

$$RfD_i \;=\; 0.286\ (m^3/kg\text{-}day) \cdot RfC_i\ (mg/m^3)$$

$$RfD_i \;=\; 2.86 \times 10^{-4}[(mg/\mu g)(m^3/kg\text{-}day)] \cdot RfC_i\ (\mu g/m^3)$$

Dermal intakes from either water or sediment are calculated as absorbed doses. To evaluate these absorbed doses, an oral RfD based on an absorbed dose must be developed. This is accomplished by adjusting the oral RfD for the absorption efficiency in the study used as the basis for this oral toxicity parameter. The oral RfD is translated into an RfD suitable for evaluating the absorbed dose from dermal exposure using the following equation:

$$RfD_d = EFF_o \cdot RfD_o$$

where:

RfD_d = reference dose for evaluating absorbed dermal doses (mg/kg-day),

RfD_o = reference dose for evaluating administered ingestion doses (mg/kg-day), and

EFF_o = absorption efficiency in the study used to develop an oral reference dose.

Carcinogenic Dose-response

For carcinogenic effects, the relevant intake is the total cumulative intake averaged over a lifetime because the quantitative dose-response function for carcinogens is based on the assumption that cancer results from cumulative lifetime exposures to carcinogenic agents. In other words, it is assumed that a finite level of risk is associated with any dose above zero. The dose-response model also assumes that there is a linear relationship throughout the range of doses and observable responses. For carcinogenic effects, EPA uses a two-step evaluation in which the chemical is assigned a weight-of-evidence classification, and then an oral cancer slope factor (CSF) and/or an inhalation unit risk factor (URF) is calculated. The weight-of-evidence classification is based on the likelihood of the compound being a human carcinogen. Group A compounds are classified as human carcinogens, Group B compounds are probable human carcinogens, Group C compounds are possible human carcinogens, Group D compounds are not classifiable as to human carcinogenicity, and Group E compounds have evidence of non-carcinogenicity for humans.

In the second part of the evaluations, CSFs and URFs are calculated for compounds that are known or probable human carcinogens. The EPA developed mathematical models that extrapolate observed responses at high doses or concentrations used in animal studies to predict responses in humans at the low doses or concentrations encountered in environmental situations. The models developed by the EPA assume no threshold and usually use animal as well as human data to develop an estimate of the carcinogenic potency of a compound. This numerical estimate is referred to by the EPA as the CSF for oral exposures and the URF for inhalation exposures. The mathematical models used by EPA assume that carcinogenic dose-response is linear at low doses.

Oral CSFs are expressed in terms of $(\text{mg/kg-day})^{-1}$, which represents the risk per average daily dose in mg/kg-day. Inhalation URFs are expressed in terms of $(\mu g/m^3)^{-1}$, which represents the risk per average concentration in air in units of $\mu g/m^3$. The inhalation cancer slope factors (CSF_i) can be calculated from inhalation URF_i values with the following equation:

$$CSF_i = 3{,}500 \ [(\mu g/m^3)/(mg/kg{-}day)] \cdot URF_i(\mu g/m^3)$$

The oral CSF is translated into a CSF suitable for evaluating the absorbed dose from dermal exposure using the following equation:

$$CSF_d = \frac{CSF_o}{EFF_o}$$

where:

CSF_d = cancer slope factor for evaluating absorbed dermal doses $(mg/kg\text{-}day)^{-1}$,

CSF_o = cancer slope factor for evaluating administered ingestion doses $(mg/kg\text{-}day)^{-1}$, and

EFF_o = absorption efficiency in the study used to develop the oral cancer slope factor.

5.6.2 Polychlorinated Biphenyls

Much information has been published on polychlorinated biphenyls (PCBs) in the past few years and a majority of the PCB review was obtained from recent literature compilations and evaluations (ATSDR and EPA, 1999; ATSDR, 1997; EPA, 1996d; Johnson *et al.*, 1998a; Cogliano, 1998). In addition, individual studies were cited particularly regarding neurobehavioral effects from exposure to PCBs, including pre- and post-natal effects (Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Koopman-Esseboom *et al.*, 1996).

PCBs are mixtures of synthetic organic chemicals which take on forms from oily liquids to waxy solids, depending on the arrangement of their common components (EPA, 1996d). There are 209 individual chlorinated biphenyl compounds, known as congeners. PCBs are often evaluated as one of seven commercially available mixtures of congeners, which contain a large percentage of all the PCBs produced and sold in the United States. Some PCB mixtures are referred to by the industrial trade name, Aroclor. The seven common Aroclors include 1016, 1221, 1232, 1242, 1248, 1254, and 1260, and the numbers indicate the number of carbon atoms and percent chlorine by weight (ATSDR, 1997). For example, Aroclor 1254 means that the molecule contains 12 carbon atoms (the first two digits) and approximately 54 percent chlorine by weight (second two digits).

Because of natural environmental processes (i.e., partitioning, chemical transformation, and preferential bioaccumulation) PCBs in the environment occur as mixtures of congeners, and their composition (and thus their toxicity) differs from the commercial mixtures. The following sections describe the range of cancer slope factors to be used, the key carcinogenic studies used to derive those slope factors, the mechanisms of carcinogenicity, the dioxin-like properties of some PCBs and their assigned toxicity equivalency factors, and the noncancer effects of PCBs.

Effect of Environmental Processes

In the environment, PCBs occur as mixtures whose compositions differ from commercial mixtures. This is because after release into the environment, mixture composition changes over time, through partitioning, chemical transformation, and preferential bioaccumulation.

Partitioning is the process by which different fractions of a mixture separate into air, water, sediment, and soil. Through partitioning, PCBs:

- Adsorb to organic materials, sediments, and soils; adsorption tends to increase with chlorine content of the PCBs and organic content of the other material (Callahan *et al.*, 1979); and

- Volatilize or disperse as aerosols, especially congeners with low chlorine content, as they tend to be more volatile and also more soluble in water (Callahan *et al.*, 1979).

Biodegradation is another environmental process by which chemical transformation of PCBs can occur. Biodegradation can occur through:

- Anaerobic bacteria in sediments by selectively removing chlorines from meta and para positions;

- Aerobic bacteria removing chlorines from PCBs with low chlorine content and breaking open the carbon rings through oxidation (Abramowicz, 1990); PCBs with higher chlorine content are extremely resistant to oxidation and hydrolysis; and

- Photolysis, which can slowly break down congeners with high chlorine content.

The dechlorination of PCBs by anaerobic bacteria and photolysis is not synonymous with detoxification, as congeners having carcinogenic activity can be formed through dechlorination (Brown and Wagner, 1990). Furthermore, the dechlorination processes are slow and altered PCB mixtures persist in the environment for many decades.

Most studies of PCB-contaminated sites demonstrate that a threshold PCB concentration must exist before anaerobic dechlorination can occur. The threshold PCB concentration level is site-specific. At different sites, thresholds have been shown to range between 10 mg/kg and 50 mg/kg. The threshold PCB concentration level for the Lower Fox River is approximately 30 mg/kg. For sediment deposits in the Lower Fox River with average concentrations greater than 30 mg/kg, an approximate 10 percent reduction in PCB mass was estimated due to anaerobic processes. No PCB reductions due to anaerobic processes can be accounted for in deposits with average PCB concentration less than 30 mg/kg. No aerobic PCB degradation has been documented in the Lower Fox River (RETEC, 2002b).

Preferential bioaccumulation is another important environmental process that occurs in living organisms where:

- PCBs are highly soluble in lipids and are absorbed by fish and other animals.

- Rates of metabolism and elimination are slow and vary by congener; thus, each species in the food chain retains persistent congeners that prove resistant to metabolism and elimination (Oliver and Niimi, 1988).

- Congeners with higher chlorine content are bioaccumulated through the food chain, producing residues that are considerably different from the original Aroclors (Lake *et al.*, 1992; Oliver and Niimi, 1988).

- Bioaccumulated PCBs in humans appear to be more persistent in the body and could be more toxic than Aroclors (as they are in animals) (Hovinga *et al.*, 1992; ATSDR, 1997); for example, a study comparing mink fed a given quantity of Aroclor 1254 with mink fed Great Lakes fish contaminated with one-third that quantity of bioaccumulated PCBs (plus other chemicals) found similar liver and reproductive toxicity (Hornshaw *et al.*, 1983).

Absorption and Retention

PCBs can be absorbed through ingestion, inhalation, and dermal exposure, after which they are transported similarly through the circulatory system. Thus, it seems logical to expect similar internal effects from different exposure routes.

PCBs are eliminated through metabolism, which occurs primarily in the liver (Matthews and Anderson, 1975; ATSDR, 1997). Metabolism rates are generally lower with high chlorine content, but chlorine position is also important (Matthews and Anderson, 1975). In addition to variability by congener, there is human variability in metabolism and elimination. People with decreased liver function, including inefficient metabolic capacities in infants whose capacity to fully metabolize and eliminate PCBs has not been developed (Calabrese and Sorenson, 1977), have less capacity to metabolize PCBs than people in the general population.

Retention of PCBs occurs in the body long after exposure stops and the biological activity of persistent congeners is also maintained. For example, the half-lives of various Aroclors and total PCBs in the body are:

- 2.6 years for Aroclor 1242 and 4.8 years for Aroclor 1254 in workers exposed to PCBs (Phillips *et al.*,1989),

- 3.1 years for Aroclor 1242 and 6.5 years for Aroclor 1254 in exposed workers (Steele *et al*., 1986),

- 2 years for Aroclor 1242 and 16 years for Aroclor 1260 in exposed workers (Steele *et al*., 1986), and

- 8 years for total serum PCBs in non-occupational exposures (Steele *et al.*, 1986).

Exposure to PCBs by eating contaminated fish yields even longer persistence of these congeners (Hovinga *et al*., 1992; ATSDR, 1997). The half-life values assigned to these congeners must be applied with caution because the half-life estimates assigned to a mixture can underestimate long-term persistence due to the composition of its components.

PCBs can cross human skin and increase body burden. Dermal exposure can contribute significantly to body burdens of workers and can be a major route of environmental exposure (ATSDR, 1997). Quantitatively, dermal exposure would pose lower risks, because PCBs are substantially but incompletely absorbed through the skin (Wester *et al.*, 1983, 1987, 1990, 1993).

Health Effects of PCBs - Literature Review

Several studies have been conducted and presented in the scientific literature regarding public health implication of PCBs and other toxic substances in the Great Lakes area. Papers have also been written which review and summarize the research findings from these numerous studies. The majority of the studies focus on exposure via fish consumption, as this route of exposure has been demonstrated to be the most significant. The collective weight of evidence from these studies indicates that exposure to PCBs found in fish can cause developmental, reproductive, immune, and neurobehavioral problems.

Two recent publications highlight some of the major research findings associated with exposure to PCBs: *Public Health Implications of Persistent Toxic Substances in the Great Lakes and St. Lawrence Basins*, by Johnson *et al.* (1998a) and *Public Health Implications of Exposure to Polychlorinated Biphenyls (PCBs)*, coauthored by the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Public Health Service, in the U.S. Department of Health and Human Services, and the EPA (ATSDR and EPA, 1999). These papers present findings in wildlife populations, laboratory studies, and in human populations that indicate a positive correlation between consumption of fish from the Great Lakes area and levels of PCBs in the body. Some of these studies include the following.

- **Hanrahan *et al.* (1997).** Frequent fish consumers (including Wisconsin anglers) had a significantly greater PCB serum level than infrequent consumers, and the total number of years of eating Great Lakes sport fish was the best predictor of PCB body burden. In a similar study (Falk *et al.*, 1999), regression analyses indicated that PCB body burden was greater in men than in women, and that lake trout and salmon consumption were significant predictors of PCB body burden.

- **Humphrey (1983).** A study of Lake Michigan fish eaters indicated that PCB levels in breast milk and maternal serum correlates with consumption of contaminated fish.

- **Anderson *et al.* (1998).** In a study of Great Lakes sport fish consumers, serum was analyzed for several constituents, including PCBs. The study group consumed an average of 49 Great Lakes sport fish meals per year, placing them in a relatively high-exposure subpopulation. The overall mean coplanar PCB levels were 10.5 times greater than selected background levels in the general population.

- **Stewart *et al.* (1999).** A study of Great Lakes fish consumers concluded that maternal consumption of fish increased the risk of prenatal exposure to the most heavily chlorinated PCB homologues. PCBs were measured in umbilical cord blood as well as breast milk, and the highest concentrations correlated to the groups that consumed the most fish.

- **Humphrey *et al.* (2000).** PCB congeners were measured in a group of Lake Michigan residents aged 50 and over (fish eaters and non-fish eaters). The evaluation indicated significant PCB exposure in the fish eaters. Furthermore, it was determined that a select subset of congeners that were most prevalent could be used as indicator congeners in blood analysis.

Many studies present findings that health effects are associated with exposure to PCBs via fish consumption. A few of the exposure studies of human populations are summarized below.

- **Courval *et al.* (1997).** A study of Michigan anglers indicated that with increasing sport-caught fish consumption (of fish contaminated with persistent toxic substances), there were increased odds for conception failure.

- **Michigan/Maternal Infant Cohort Study (Fein *et al.*, 1984b; Jacobson *et al.*, 1985, 1990a, 1990b).** Developmental disorders and cognitive deficits were noted in offspring of mothers exposed to persistent toxic substances for 6 years before and during pregnancy via fish consumption. A follow-up study (Jacobson and Jacobson, 1996) showed that neurodevelopmental deficits assessed at birth were still persistent at age 11.

- **Lonky *et al.*, (1996).** Newborns of high-fish-consuming mothers exhibited a greater number of abnormal reflexes, less mature autonomic responses, and less attention to visual/auditory stimuli in comparison to newborns of no- or low-fish-consuming mothers.

- **Smith (1984) and Humphrey (1988).** Maternal serum PCB levels during pregnancy (of women who consumed contaminated Great Lakes/St. Lawrence fish) were positively associated with the number and type of infectious illnesses which occurred in infants.

- **Kostyniak *et al.* (1999).** A study of nursing mothers who consumed sport-caught fish from Lake Ontario evaluated PCB levels in breast milk. The higher-fish-consuming groups had higher levels of PCBs in breast milk. The study concluded that an inverse relationship exists between the concentration of PCBs and the overall duration of lactation for these women.

Additional studies report health effects associated with PCB exposure by other routes, such as ingestion of cooking oil. In two separate cases in Taiwan and Japan, PCB-contaminated bottles of rice oil and cooking oil resulted in an outbreak of illness (referred to as Yu-Cheng and Yusho disease, respectively) which included chloracne, hyperpigmentation, and meibomian gland dilation (Rogan *et al*., 1988). Even several years after the incident, women who were exposed to the contaminated oil gave birth to infants with abnormalities. The exposed children were small for gestational age and had abnormalities of the lungs, skin, and teeth. In addition, these children exhibited a delay in mental and psychomotor development. Follow-up studies of the Taiwan case have shown that neurobehavioral deficits and developmental delays may persist in older children (Chen *et al.*, 1992; Guo *et al.*, 1995; Chao *et al.*, 1997). However, it should be noted that these results may have been associated with the presence of dibenzofurans which were also present in the contaminated oil.

The following studies associate neurological impairments in infants with mothers who were exposed to PCBs.

- **Huisman *et al.* (1995a, 1995b).** This study revealed that PCBs, dioxins, and furans present in breast milk were associated with reduced neonatal neurologic optimality in breast-fed infants 2 to 3 weeks old. In addition, increased hypertonia in these infants was associated with high levels of coplanar PCBs in breast milk. These effects were also noted when the group of children was studied at 18 months old (Huisman *et al.*, 1995b); however at 42 months of age, the effects were no longer observed (Lanting *et al.*, 1998).

- **Koopman-Esseboom *et al.* (1996).** Exposure to PCBs and dioxins in infants (*in utero* as well as via breast-feeding) was evaluated to determine the effects on mental and psychomotor development. The authors found that prenatal PCB exposure had a small negative effect on psychomotor development at 3 months, although at 7 and 18 months psychomotor development was comparable between breast-fed and formula-fed infants. PCB/dioxin exposure did not appear to significantly influence mental development in any age group.

The following studies associate immunological effects with individuals exposed to PCBs.

- **Tryphonas (1995).** Effects on the immune system were studied in the Yu-Cheng and Yusho populations. Adverse effects included persistent respiratory distress (in half of Yu-Cheng persons studied); decreases in antibody levels 2 years after exposure (normal at 3 years); decrease in percentage of T-lymphocytes (Yu-Cheng) and increase in T-helper cells and decrease in T-suppressor cells (Yusho) 14 years after exposure; and enhanced responses to mitogens (Guo *et al.*, 1995).

- **Weisglas-Kuperus *et al.* (1995).** Studies of infants exposed to PCBs and dioxins pre- and postnatally indicated lower monocyte and granulocyte counts for 3-month-old infants, and increased total T-cell counts and cytotoxic T-cell counts for children 18 months old.

- **Hagmar *et al.* (1995).** Elevated PCB serum levels were significantly correlated with a decrease in natural killer cells. This was also found to occur with p,p'-DDT and two PCB congeners. No changes were observed for other lymphocyte cells.

- **Weisglas-Kuperus *et al.* (2000).** The effects of prenatal exposure to PCBs and dioxins were shown to persist into childhood and might be associated with a greater susceptibility to infectious diseases.

Some studies have not been able to demonstrate a positive correlation between PCB exposure and adverse health effects. However, these studies should be viewed as inconclusive, rather than evidence that supports PCBs are **not** associated with adverse health effects. Some examples of these studies are presented below.

- **Dar *et al.* (1992).** PCB serum levels were measured in a population of pregnant women from the Green Bay, Wisconsin area. A positive correlation was found between the PCB serum levels and the amount of Lake Michigan fish consumed in the past and present. In addition, reproductive outcome measures were evaluated for newborns of these women. For mothers who gained less than 34 pounds during their pregnancy, a positive correlation was found between mothers' PCB serum levels and birth size. This finding was contrary to results from other studies. However, in contrast with other studies, the population did not include high-end fish consumers, so PCB exposure may have been insufficient to create adverse noncancer responses.

- **Schantz *et al.* (1996).** A study was designed to assess the effects of PCBs and DDE in elderly Great Lakes sport anglers. Results were presented at the Health Conference '97 Great Lakes and St. Lawrence (Schantz *et al.*, 1997). The levels of PCBs measured in serum were clearly elevated in the fish eaters versus the non-fish eaters and relative to typical background levels. However, adjusted results of the study indicated that PCB and DDE levels did not impair fine motor function. A similar study (Schantz *et al.*, 1999) corroborated the previous findings.

- **Buck *et al.* (1999).** This study was conducted to determine potential reproductive effects of exposure to PCBs via consumption of Lake Ontario fish. Paternal fish consumption histories were evaluated, and correlated to the length of time taken for their partner to become pregnant. The study concluded that Lake Ontario fish consumption does not increase the risk of conception delay.

To summarize, the vast weight of evidence from human population studies indicates that exposure to PCBs, including PCBs found in fish from the Great Lakes area, can cause a variety of adverse health effects. These include developmental, immunological, reproductive, and neurobehavioral problems. Continuing research will provide more information on the human health effects of PCBs and the implications to populations at higher risk of exposure.

Carcinogenicity

Several studies demonstrate the carcinogenic effects of PCBs in rats and mice. Table 5-36 summarizes these key studies in addition to key human epidemiological studies.

New toxicity information from a cancer study of four commercial mixtures (Aroclor 1016, 1242, 1254, and 1260) demonstrates that all PCB mixtures can cause cancer, although different mixtures have different potencies (Brunner *et al.*, 1996). All mixtures induced liver tumors when fed to female rats; Aroclor 1260 also induced liver tumors in male rats (Brunner *et al.*, 1996). The importance of this data is that these four mixtures contain overlapping groups of congeners that, together, span the range of congeners most often found in environmental mixtures.

It is also important to note that some studies have concluded that PCBs are not carcinogenic in humans based upon negative epidemiological studies (Kimbrough *et al*., 1999). ATSDR, with the concurrence of an expert panel, concluded that the Kimbrough study could not be used to dismiss the potential carcinogenicity of PAHs (Bove *et al*., 1999). The ATSDR identified several inadequacies in the Kimbrough study, and they provided references to extensive studies on carcinogenicity in animals, as well as studies that suggest a relationship between PCB exposures and excess cancer in humans.

Mechanism of Carcinogenicity. Several mechanisms have been proposed for the carcinogenicity of PCBs including:

- Tumor-promoting activity in liver or lung from Aroclor 1254 and some congeners with four to six chlorines (Silberhorn *et al.*, 1990).

- Induction of mixed-function oxidases (i.e., phenobarbital-type inducers, 3-methylcholanthrene-type inducers, and mixed inducing properties), resembling chlorinated dibenzo-p-dioxins and dibenzofurans in structure and toxicity (Buchmann *et al.*, 1986, 1991) and present in mixtures with either high or low chlorine content.

- Dihydroxy metabolites of PCBs with low chlorine content are activated to reactive intermediates that produce oxidative DNA damage (Oakley *et al.*, 1996)—possible for environmental PCB association with human breast cancer.

- A highly significant statistical relationship between PCB blood levels and increased probability of non-Hodgkin lymphoma (Rothman *et al.*, 1997), and immune system suppression in association with the immunosuppressive characteristics of non-Hodgkin lymphoma from dioxin-like and non-dioxin-like congeners (Hardell *et al.*, 1996).

- Possible endocrine disruption similar to both dioxin-like and non-dioxin-like congeners (Birnbaum, 1994; Birnbaum and DeVito, 1995).

- Induction of thyroid carcinomas similar to 2,3,7,8-TCDD by increasing the metabolism and excretion of the thyroid hormone (NTP, 1983; McClain, 1989).

As demonstrated by these various mechanisms, different PCB congeners are capable of inducing cancer by different mechanisms.

Dioxin-like Congeners of PCBs. Relatively few PCB congeners resemble 2,3,7,8-TCDD in structure, toxicity, and as just indicated, in carcinogenic mechanism. However, it is important to recognize that both dioxin-like and non-dioxin-like mechanisms contribute to the overall PCB toxicity. The similarities these dioxin-like PCB congeners have in common with dioxin include:

- Similar carcinogenic mechanisms (endocrine disruption and induction of thyroid cancer via thyroid hormone regulation),

- Some PCB congeners acting as 3-methylcholanthrene-type inducers or possessing other dioxin-like inducing capacity,

- Toxic responses similar to dibenzo-p-dioxins and dibenzofurans, all acting through the aryl hydrocarbon receptor, and

- Persistence and accumulation in the food chain.

It is important to consider the contribution of these congeners to total dioxin equivalents. In some cases, PCBs can contribute more dioxin-like toxicity than chlorinated dibenzo-p-dioxins and dibenzofurans (Ahlborg *et al.*, 1994). The use of dioxin toxicity equivalency factors (TEFs) for dioxin-like congeners is discussed in the next section. It is also recognized that since the mechanism of PCB toxicity often varies from the mechanism of dioxins and furans for cancer induction, the use of TEFs is still undergoing evaluation.

Derivation and Application of Cancer Slope Factors. Previous assessments developed a single dose-response slope (7.7 per mg/kg-day average lifetime exposure) for evaluating PCB cancer risks (EPA, 1988). This slope factor was used by default for any PCB mixture because before 1996, only commercial mixtures with 60 percent chlorine (Aroclor 1260) had been adequately tested.

Brunner *et al.*'s cancer study (1996) of four commercial mixtures (Aroclor 1016, 1242, 1254, and 1260) demonstrated that all PCB mixtures can cause cancer, although different mixtures have different potencies (Cogliano, 1998). The resulting new upper-bound slopes are lower than the previous slope factor of 7.7 per mg/kg-day which was based upon Aroclor 1260. The new approach to assessing the cancer risk from environmental PCBs distinguishes among PCB mixtures by using information on environmental processes. Environmental processes have profound effects that can decrease or increase toxicity, so toxicity of an environmental mixture is only partly determined by the original commercial mixture. This new EPA approach, which has undergone external peer review, considers:

- A range of upper-bound potency estimates for PCB mixtures, plus a range of central estimates, with guidance for choosing estimates from these ranges to reflect the effect of environmental processes affecting a mixture's toxicity.

- A tiered approach that can use site-specific congener information when available (i.e., presence or absence of congeners and metabolites that contribute to cancer induction), but can be adapted if information is limited to total PCBs encountered through each pathway.

- An approach that assesses risks from different exposure pathways, less-than-lifetime and early-life exposures, and mixtures containing dioxin-like compounds.

- Application of EPA's proposed cancer guidelines (EPA, 1996b) in the quantitative dose-response assessment, including the cross-species scaling factor and discussion of circumstances affecting cancer risk.

- Extrapolation of doses below the experimental range, considering both linear and nonlinear approaches.

The new approach (EPA, 1996b) involves a tiered approach, using exposure pathways to choose appropriate potency values. The highest observed potency of 1 $(mg/kg\text{-}day)^{-1}$ (central slope) or 2 $(mg/kg\text{-}day)^{-1}$ (upper-bound slope) is appropriate for pathways where environmental processes tend to increase risk such as:

- Food chain exposure, including fish consumption;

- Sediment and soil ingestion;

- Dust and aerosol inhalation;

- Dermal exposure, if an absorption factor has been applied to reduce the external dose;

- Presence of dioxin-like, tumor-promoting, or persistent congeners in other media; and

- Early-life exposure (all pathways and mixtures).

Lower potencies of 0.3 $(mg/kg\text{-}day)^{-1}$ (central slope) or 0.4 $(mg/kg\text{-}day)^{-1}$ (upper-bound slope) are appropriate for pathways where environmental processes tend to decrease risk:

- Ingestion of water-soluble congeners;

- Inhalation of evaporated congeners; and

- Dermal exposure, if no absorption factor has been applied to reduce the external dose.

The lowest potencies of 0.04 $(mg/kg\text{-}day)^{-1}$ (central slope) or 0.07 $(mg/kg\text{-}day)^{-1}$ (upper-bound slope) are appropriate when:

- Congener or isomer analyses verify that congeners with more than four chlorines comprise less than 0.5 percent of total PCBs.

Table 5-37 summarizes the cancer slope factors that are used in this analysis. These values are summarized by pathway and persistence (i.e., whether the mixture of PCBs has more than 0.5 percent congeners with more than four chlorines—high persistence). For dermal contact with sediment, absorbed doses are calculated, so the higher potencies of 1 $(mg/kg\text{-}day)^{-1}$ (central) and 2 $(mg/kg\text{-}day)^{-1}$ (upper-bound) are applicable for this pathway. For dermal contact with water, absorbed doses are also calculated; however, lower molecular weight PCBs with fewer chlorine atoms per molecule are expected to preferentially partition to water. Thus, the lower potencies of 0.3 $(mg/kg\text{-}day)^{-1}$ (central) and 0.4 $(mg/kg\text{-}day)^{-1}$ (upper-bound) are appropriate for analysis of this pathway. No adjustment for the oral to dermal route was made, since the absorption of PCBs, particularly lower molecular weight PCBs, is over 90 percent via ingestion (ATSDR, 1997). Therefore, the cancer slope factor for evaluating absorbed dermal doses is essentially the same as the cancer slope factor for evaluating administered ingestion doses.

The dioxin toxicity equivalency factor (TEF) approach will also be applied. Table 5-38 presents TEFs for PCB congeners that are believed to exhibit dioxin-like characteristics. TEFs have been developed by the EPA (1996d) and by the World Health Organization (WHO, 1997). The TEFs can be used two ways. TEFs can be multiplied by the dioxin cancer slope factors (next section) to estimate cancer slope factors for specific congeners. The former approach is utilized in this analysis. Alternatively, concentrations of PCB congeners can be multiplied by TEFs to give an equivalent concentration of 2,3,7,8-TCDD. For many congeners, the EPA and WHO values are the same; however, for PCB-77 there is a five times greater EPA TEF, and for PCB-170 and PCB-180 a TEF from WHO is not available. In addition, WHO provides a TEF for PCB-81, while EPA does not. This risk assessment incorporates the EPA TEFs into the calculations.

Noncancer Effects

Overview of Noncancer Effects. PCBs have significant human health effects other than cancer, including neurotoxicity, reproductive and developmental toxicity, immune system suppression, liver damage, chloracne, skin irritation, and endocrine disruption (EPA, 1996d; ATSDR, 1997; ATSDR and EPA, 1999). These toxic effects have been observed from acute and chronic exposures to PCB mixtures with varying chlorine content. A more detailed discussion of these effects is presented in the following section.

Cases of severe chloracne were reported in a work environment in which PCB air levels were found to be between 5.2 and 6.8 mg/m^3. The workers developing chloracne had been exposed for 2 to 4 years. Other analyses revealed worker complaints of dry sore throat, skin rash, gastrointestinal disturbances, eye irritation, and headache at work area concentrations of 0.013 to 0.15 mg PCBs per cubic meter (PCB/m^3). Higher blood PCB levels are associated with higher serum triglyceride and/or cholesterol levels, as well as high blood pressure. Air PCB concentrations as low as 0.1 mg/m^3 can produce toxic effects, and exposure to levels producing no overt toxicity can affect liver function. Recovery after termination of exposure occurs, but is slow and depends upon the amount of PCBs stored in adipose tissue (Clayton and Clayton, 1981).

Human exposures to PCBs resulting in toxic effects have been documented from the ingestion of rice oil contaminated with "Kanechlor 400" in Japan (resulting in Yusho or rice oil disease) or from industrial exposure. Clinical symptoms of poisoning included acne-like skin eruptions (chloracne), eyelid edema, conjunctival discharge, skin and nail pigmentation, and hyperkeratosis. Yusho patients are estimated to have ingested approximately 0.07 mg/kg-day for at least 50 days. The rice oil was found to be contaminated with polychlorinated dibenzofuran, which is believed to have played a significant role in the observed toxicity (Bandiera *et al.*, 1984; Kashimoto *et al.*, 1981).

Bioaccumulated mixtures are of greatest concern, because they appear to be more toxic than commercial mixtures and more persistent in the body (Hovinga *et al.*, 1992). Two highly exposed populations are exposed to bioaccumulated mixtures. One is nursing infants, for whom average intake of total PCBs was estimated at 1.5 to 27 micrograms per kilogram per day (μg/kg-day) (ATSDR, 1997), 3 to 11 μg/kg-day (WHO, 1993), or 2.1 μg/kg-day (Kimbrough, 1995), compared to 0.2 μg/kg-day estimated for adults (WHO, 1993; Kimbrough, 1995). Dietary intake varies widely, often depending on proximity to where PCBs were released into the environment. Using the narrower range (3 to 11 μg/kg-day), average daily intake for a 5-kg nursing infant would be 15 to 55 μg, about triple the average adult intake, and approximately 50-fold higher when adjusted for body weight.

Fein *et al.* (1984a, 1984b) studied the effects of low-level chronic exposure to PCBs in pregnant women and their newborn offspring from consumption of Lake

Michigan fish. Low levels of PCBs were reported to cause decreases in birth weight, head circumference, and gestational age of the newborn. PCBs were apparently transmitted to the fetus across the placenta and to the newborn through breast milk. Behavioral deficiencies, including immaturity of reflexes and depressed responsiveness, were reportedly observed in infants exposed to PCBs (Fein *et al.*, 1984a, 1984b).

The second highly exposed population to bioaccumulated mixtures is people whose diet is high in game fish, game animals, or products of animals contaminated through the food chain (EPA, 1996d). For example, recreational or high-intake fish consumers and their families who frequently eat fish from a contaminated source have higher PCB exposures than the general population (Johnson *et al.*, 1998a; ATSDR, 1997; ATSDR and EPA, 1999; Anderson *et al.*, 1998; Hanrahan *et al.*, 1997).

Reference Doses for PCB Aroclors. Two of the PCB Aroclors have oral reference doses available on IRIS, Aroclor 1016, and Aroclor 1254. The studies that the RfDs are based on, the critical target organs, and the confidence in the RfDs along with the uncertainty and modifying factors are detailed below. In this assessment, the oral RfD for Aroclor 1254 has been used to evaluate Aroclors 1221, 1232, 1242, 1248, and 1260 as well.

Aroclor 1016. The oral RfD of 7.0E-5 mg/kg-day is based on a series of reports that evaluated perinatal toxicity and long-term neurobehavioral effects of Aroclor 1016 in the same group of infant monkeys (Barsotti and Van Miller, 1984; Levin *et al.*, 1988; Schantz *et al.*, 1989, 1991). Aroclor 1016 was administered to groups of eight adult female rhesus monkeys via diet in concentrations of 0, 0.25, and 1.0 ppm for approximately 22 months. Exposure began 7 months prior to breeding and continued until offspring were weaned at age 4 months. A decrease in birth weight in the high-dose group was significantly lower in controls (p, 0.01) (Barsotti and Van Miller, 1984). The offspring of the high-dose group were significantly ($p < 0.05$) impaired in behavioral testing (Schantz *et al.*, 1989). Behavioral and neurological dysfunctions, including deficits in visual recognition and short-term memory, also have been observed in infants of human mothers who consumed fish contaminated with PCB mixtures (Fein *et al.*, 1984a, 1984b; Jacobson *et al.*, 1985, 1984; Gladen *et al.*, 1988; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996).

The RfD is based on the low dose of 0.25 ppm (0.007 mg/kg-day) from the Schantz *et al.* (1989, 1991) studies. This dose was considered a NOAEL. An uncertainty factor of 100 is applied to account for sensitive individuals, extrapolation from monkeys to humans, limitations in the database, and partial extrapolation from subchronic exposure to chronic. A modifying factor of 1 indicates that no modification was done. The study, the database, and the RfD carry a medium level of confidence according to EPA, since essentially only one group of monkeys was examined.

The absorption of PCBs through ingestion has been estimated to be over 90 percent, particularly for mixtures such as Aroclor 1016 with the lowest number of chlorine atoms per PCB molecule (ATSDR, 1997). Therefore, an absorption factor of 1.0 was assumed for this Aroclor, so that the dermal RfD is the same as the oral RfD.

Aroclor 1254. The oral RfD of 2.0E-5 mg/kg-day was obtained from studies conducted by Arnold *et al.* (1993a, 1993b) and Tryphonas *et al.* (1989, 1991a, 1991b). Groups of 16 adult female rhesus monkeys ingested gelatin capsules of Aroclor 1254 at dosages of 0, 5, 20, 40, or 80 micrograms per kilogram per day (μg/kg-day) for more than 5 years. After 25 months of exposure, the monkeys had achieved a pharmacokinetic steady-state based on PCB concentrations in adipose tissue and/or blood (Tryphonas *et al.*, 1989). General health status was evaluated daily, and body weight measurements, feed conversion ratio calculations, and detained clinical evaluation were performed weekly throughout the study. Analyses of clinical signs of toxicity were limited to the occurrence of eye exudate, inflammation and/or prominence of the eyelid Meibomian (tarsal) glands, and particular changes in finger- and toe-nails (prominent nail beds, separation from nail beds, elevated nail beds, and nails folding on themselves). Monkeys that ingested 5 to 80 μg/kg-day doses of Aroclor 1254 showed ocular exudate, prominence and inflammation of the Meibomian glands, and distortion in nail bed formation. These changes were seen at the lowest dose tested and a dose-dependent response was demonstrated. Similar changes have been documented in humans for accidental oral ingestion of PCBs (EPA, 1998a). The RfD for Aroclor 1254 is based on the low dose of 5 μg/kg-day from the study. An uncertainty factor of 300 was applied to account for sensitive individuals, extrapolation from rhesus monkeys to humans, interspecies extrapolation, and the extrapolation of a subchronic to chronic study. The modifying factor of 1 indicates that no modification was done. The study, the database, and the RfD carry a medium level of confidence according to EPA.

The absorption of PCBs through ingestion has been estimated to be 75 to 100 percent for PCB mixtures (ATSDR, 1997), although mixtures with higher chlorine content appear to have somewhat lower absorption. An absorption factor of 90 percent was used to translate the oral RfD to an RfD suitable for evaluating dermal exposure. The conversion is as follows:

$$2 \times 10^{-5}\ mg/kg\text{-}day * 0.9 = 1.8 \times 10^{-5}\ mg/kg\text{-}day$$

5.6.3 Polychlorinated Dibenzo-p-dioxins and Dibenzofurans

The polychlorinated dibenzodioxins (dioxins) include 75 individual compounds, and the polychlorinated dibenzofurans (furans) include 135 individual compounds. These individual compounds are technically referred to as congeners. Both PCDDs and PCDFs have eight positions on their molecules where chlorine atoms can substitute for hydrogen atoms. Only seven of the 75 congeners of PCDDs are thought to have dioxin-like toxicity; these have chlorine substitutions in the 2, 3, 7, and 8 positions. Only 10 of the 135 possible congeners of PCDFs are thought to have dioxin-like toxicity; these have substitutions in the 2, 3, 7, and 8 positions. The toxicities of dioxin and furan congeners are evaluated relative to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), the most extensively studied of the dioxin and furan congeners.

Non-carcinogenic effects from short-term or long-term exposure to dioxins/furans are numerous. These effects can range from nose, throat, and lung irritation to headaches, dizziness, nausea, vomiting, nervous system and skin disorders, and potential damage to the liver, pancreas, circulatory and respiratory systems, depending on the duration and severity of exposure (Sittig, 1991).

The carcinogenicity of dioxins has been thoroughly investigated through numerous studies and experiments to determine its potential impacts to human health. Of the data that are available, there is sufficient evidence to conclude that 2,3,7,8-TCDD is carcinogenic in experimental animals (Class B2). A number of experiments with rats and mice has demonstrated that the incidence of liver tumors consistently increased in males and females with the dermal and oral administration of 2,3,7,8-TCDD (McGregor *et al.*, 1998). In addition, other cancers have been observed in experimental animals such as lymphomas, alveolar and bronchiolar adenomas and carcinomas, and thyroid follicular cell adenomas depending on the animal species, sex, and route of administration (McGregor *et al.*, 1998).

Human data on the carcinogenicity of dioxins is inconclusive, but there is limited epidemiological evidence in humans to support the carcinogenicity of 2,3,7,8-TCDD. Various investigations show a weak link between occupational and environmental exposures of 2,3,7,8-TCDD and carcinogenicity in humans. The most important information on the carcinogenicity of 2,3,7,8-TCDD related to human exposure has been done through cohort studies in areas with varying degrees of 2,3,7,8-TCDD contamination. Overall, an increased risk for all cancers combined was seen across the cohort studies rather than for any specific site (McGregor *et al.*, 1998). The largest magnitude of increase generally occurred in subcohorts considered to have the highest 2,3,7,8-TCDD exposure within cohort groups. Most commonly, lung cancers were observed amongst these more highly exposed subcohorts (McGregor *et al.*, 1998).

Information on the carcinogenicity of furans is less available than that for dioxins. There have been no long-term studies on experimental animals with furans to adequately determine the carcinogenicity of these compounds (McGregor *et al.*, 1998). The results are likewise for human data. A few epidemiological cases studies were followed to investigate exposure to furans, but the data showed inadequate evidence to conclude the carcinogenicity of furans in humans (McGregor *et al.*, 1998).

Derivation of Cancer Slope Factor

Based on a study done by Kociba *et al.* (1978) the EPA has derived a cancer slope factor of 150,000 $(mg/kg\text{-}day)^{-1}$ for both the oral and inhalation exposure routes associated with 2,3,7,8-TCDD. Calculations were based on the increased incidence of tumors of the lungs and liver in female rats fed diets containing 2,3,7,8-TCDD for 2 years (EPA, 1985b). This value is currently under review and is subject to change with further investigation. In this analysis, the oral CSF is used to evaluate absorbed doses estimated for the dermal pathway.

For risk assessment purposes, oral and inhalation CSFs have been derived using toxicity equivalency factors (TEFs) for the dioxin/furan congeners. This procedure involves assigning individual TEFs to the dioxin or furan congeners. TEFs are estimates of the toxicity of dioxin-like compounds relative to the toxicity of 2,3,7,8-TCDD, which is assigned a TEF of 1.0. All other congeners have TEF values that are equal to or less than the TEF of 2,3,7,8-TCDD; these TEFs range from 0.00001 to 1.0. TEF values for dioxin and furan congeners are presented in Table 5-39. TEFs have been developed by the EPA (1989b) and WHO (1997). The TEFs can be used two ways. TEFs can be multiplied by the CSF for 2,3,7,8-TCDD to yield a CSF for the specific congener. Alternatively, the concentration of the congener can be multiplied by its TEF to calculate an equivalent concentration of 2,3,7,8-TCDD. For many congeners, the EPA and WHO values are the same; however, for 2,3,7,8-PCDD the WHO TEF is twice that of EPA's, and for OCDD and OCDF, the EPA TEF is 10 times greater than the WHO value. This risk assessment incorporates the EPA TEFs into the calculations.

Derivation of Reference Dose

No RfDs for either ingestion or inhalation are available on IRIS. An oral RfD of 10^{-9} mg/kg-day (1 picogram per kilogram per day [pg/kg-day]) had previously been established for 2,3,7,8-TCDD, but this value has been withdrawn from IRIS. This value will be used in this evaluation for 2,3,7,8-TCDD to evaluate non-carcinogenic effects of oral and dermal exposure (EPA policy). The non-carcinogenic effects of inhalation exposure will not be evaluated.

5.6.4 Dieldrin

Dieldrin is a chlorinated organic pesticide and causes a variety of non-carcinogenic effects when short-term acute exposure or long-term chronic exposure occurs. Such effects include nausea, dizziness, headaches, muscle twitches, convulsions, and skin and eye disorders (Sittig, 1991).

Several toxicological studies of dieldrin done on animals have yielded sufficient evidence to conclude it is a carcinogenic compound (Class B2). Dieldrin, which is structurally related to compounds which produce tumors in rodents (aldrin, chlordane, heptachlor epoxide, and chlorendic acid), caused benign liver tumors and hepatocarcinomas at different dose levels in various strains of mice of both sexes when administered orally.

Human carcinogenic data for dieldrin is inadequate to draw the same conclusions reached by animal studies. Two studies which followed workers exposed to aldrin and to dieldrin reported no increased incidence of cancer. Both studies were limited in their ability to detect an excess of cancer deaths. Van Raalte (1977) observed two cases of cancer (gastric and lymphosarcoma) among 166 pesticide manufacturing workers exposed 4 to 19 years and followed from 15 to 20 years. Exposure was not quantified, and workers were also exposed to other organochlorine pesticides (endrin and telodrin). The number of workers studied was small, the mean age of the cohort (47.7 years) was young, the number of expected deaths was not calculated, and the duration of exposure and of latency was relatively short. Recent data have also linked dieldrin exposure to increased incidence of breast cancer (Hoyer *et al*., 1998). Organochlorines are believed to mimic the effects of estrogen, which promotes tumor growth in breast cancer. A Danish study of over 7,000 women monitored for 19 years found that women with the highest levels of dieldrin in their blood were twice as likely to develop breast cancer as women with the lowest levels.

Derivation of Cancer Slope Factors

The oral and inhalation cancer slope factor of 1.6E+01 $(mg/kg\text{-}day)^{-1}$ is based on the geometric mean of 13 slope factors calculated from liver carcinoma data in both sexes of several strains of mice fed diets of dieldrin. Inspection of the data indicated no strain or sex specificity of carcinogenic response. For this assessment, the oral CSF is used to evaluate absorbed doses for the dermal exposure pathway.

Derivation of Reference Dose

The oral reference dose of 5.0E-05 mg/kg-day for dieldrin was calculated based on an experiment by Walker *et al.* (1969) where dieldrin was administered to rats for 2 years at dietary concentrations approximately equal to 0, 0.005, 0.05, and 0.5 mg/kg-day. Body weight, food intake, and general health remained unaffected throughout the 2-year period, although at 0.5 mg/kg-day all animals became irritable and exhibited tremors and occasional convulsions. No effects were seen in various hematological and in clinical chemistry parameters. At the end of 2 years, females fed 0.05 and 0.5 mg/kg-day had increased liver weights and liver-to-body weight ratios ($p < 0.05$). Evidence of hepatic lesions were considered to be characteristic of exposure to an organochlorine insecticide. The LOAEL was identified as 0.05 mg/kg-day and the NOAEL as 0.005 mg/kg-day. For this assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathway.

5.6.5 DDT, DDE, and DDD

DDT is a chlorinated organic pesticide that is generally made up of a complex mixture of DDT isomers and metabolites. DDD and DDE are the metabolites most commonly associated with technical-grade DDT and result from degradation of the mixture. DDT, DDD, and DDE are structurally very similar, so their behavior in the environment is similar as well (ICF, 1985).

DDT and its metabolites, DDD and DDE, have been classified by EPA as probable human carcinogens based on adequate studies in animals and inadequate studies in humans (Class B2). Human exposure to DDT is primarily by ingestion of contaminated food. By EPA estimates, total intake of DDT each year for the average U.S. resident is less than 3 milligrams per year (mg/yr) (Sittig, 1991). Points of attack include the central nervous system, liver, kidneys, skin, and peripheral nervous system. DDT is of moderate toxicity to man and most other organisms. However, its extremely low solubility in water (0.0012 mg/L) and high solubility in fat (100,000 ppm) result in great bioconcentration (Sittig, 1991). Symptoms of overexposure include paresthesia of the tongue, lips, and face; tremors; apprehension; dizziness; confusion; malaise; headache; convulsions; paresis of the hands; vomiting; and irritation of the eyes and skin (Sittig, 1991).

Exposure to DDT may also result in behavioral and cognitive effects. A study by Eriksson *et al*. (1990a) indicated that DDT (along with a metabolite conjugated to a fatty acid, DDOH-PA) affects muscarinic cholinergic receptors in the neonatal mouse brain when administered to suckling mice during periods of rapid brain growth. In a follow-up study, Eriksson *et al*. (1990b) found that neonatal exposure to a single low oral dose of DDT and DDOH-PA can lead to a permanent hyperactive condition in adult mice.

Derivation of Cancer Slope Factors

EPA has derived an oral cancer slope factor for DDT and DDE of 0.34 (mg/kg-day)$^{-1}$. In addition, the 0.34 (mg/kg-day)$^{-1}$ also serves as the inhalation cancer slope factor for DDT. The oral cancer slope factor for DDD, a structural analog to DDT and DDE, is 0.24 (mg/kg-day)$^{-1}$ based on extrapolation of data from a study done by Tomatis *et al.* (1974) where evidence of liver tumors was discovered in mice fed a diet of DDD. For this assessment, the oral CSFs are used to evaluate absorbed doses for the dermal pathways.

Derivation of Reference Dose

An oral RfD has been established for DDT of 0.0005 mg/kg-day based on a NOAEL of 0.05 mg/kg-day from a 27-week rat feeding study in which liver lesions were the observed effect (Laug *et al.*, 1950). The uncertainty factor associated with this value is 100. No RfDs have been established for the inhalation route of exposure by DDT, or for either route by DDE and DDD. For this assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathways.

5.6.6 Arsenic

The toxicity of arsenic depends upon its chemical form along with the route, dose, and duration of exposure. In general, arsenites (As^{3+}) are potentially more toxic than arsenates, soluble arsenic compounds are potentially more toxic than insoluble compounds, and inorganic arsenic compounds are potentially more toxic than organic derivatives (EPA, 1985a).

There is sufficient evidence that arsenic is a human carcinogen. Arsenic exposure has been linked to skin cancers and cancers of multiple organs (liver, kidney, lung and bladder) associated with oral exposure and inhalation exposure. EPA classifies arsenic as a Class A human carcinogen. There is inadequate evidence for the carcinogenicity of arsenic chemicals in animals.

Acute toxic effects are generally seen following ingestion of inorganic arsenic compounds; these include throat constriction, epigastric pain, vomiting, and watery diarrhea. The lethal dose for humans is reported to be 1.0 to 2.6 mg/kg-BW (Vallee *et al.*, 1960). While these effects were observed in controlled laboratory situations, the most relevant effects for the Lower Fox River and Green Bay risk assessment are long-term subchronic or chronic effects from exposure to low concentrations of arsenic.

Derivation of Cancer Slope Factors

The EPA has provided an oral CSF of 1.5 (mg/kg-day)$^{-1}$ in IRIS (EPA, 1998c). This oral CSF is based on a 1977 study, conducted by Tseng (1977), of a Taiwan population that was exposed to arsenic contamination of a water supply (EPA, 1998c). There has not been consistent demonstration of arsenic carcinogenicity in test animals for various chemical forms administered by different routes to several species. As a result, the uncertainties associated with ingested inorganic arsenic are such that estimates could be modified downwards as much as an order of magnitude relative to risk estimates associated with most other carcinogens (EPA, 1998c).

The majority of tests in which experimental animals were exposed orally to a variety of arsenic compounds produced negative results regarding carcinogenicity (Hueper and Payne, 1962; Byron *et al.*, 1967). A few studies have, however, reported tumorigenic effects of arsenic treatment (Schrauzer *et al.*, 1978). Epidemiological studies conducted in the U.S. have failed to correlate the incidence of skin cancer with arsenic in drinking water (Morton *et al.*, 1976; Goldsmith *et al.*, 1972). A dose-response relationship between the occurrence of skin cancer and arsenic consumption in the drinking water of Taiwanese, however, was reported by Tseng (1977). Arsenic exposure at certain doses may produce a pattern of skin disorders, hyperpigmentation, and keratosis that may develop into basal or squamous cell carcinoma (EPA, 1985a). Several epidemiological studies of workers occupationally exposed to arsenic have reported a correlation between this exposure and mortality due to respiratory cancer (Higgins *et al.*, 1982; Enterline and Marsh, 1982; Brown and Chu, 1983).

To evaluate dermal exposures, a CSF based on an absorbed dose must be calculated. The oral CSF is based on an epidemiological study of people ingesting arsenic in their drinking water. Dollarhide (1993) reported that 95 percent of ingested arsenic in water is absorbed. Therefore, the CSF on an absorbed dose is 1.5 (mg/kg-day)$^{-1}$/0.95 or 1.6 (mg/kg-day)$^{-1}$.

The EPA has reported the unit risk for arsenic to be 4.3E-03 (μg/m^3). The inhalation slope factor of 1.5E+01 (mg/kg-day)$^{-1}$ was calculated using the equations presented earlier. The unit risk was based on the results of two studied populations of smelter workers (EPA, 1984b). Observed lung cancer incidence was significantly increased over expected values. Mixed results regarding carcinogenicity were reported in arsenic inhalation studies (Ishinishi *et al.*, 1977; Ivankovic *et al.*, 1979).

Derivation of Reference Dose

Subchronic effects from oral exposure to arsenic include hyperpigmentation (melanosis), multiple arsenical keratoses, sensory-motor polyneuropathy, persistent chronic headache, lethargy, gastroenteritis, and mild iron deficiency anemia. Chronic oral exposure of humans to inorganic arsenic compounds has been reported to cause skin lesions, peripheral vascular disease, and peripheral neuropathy (Silver and Wainman, 1952).

A chronic and subchronic oral RfD has been established for arsenic of 0.0003 mg/kg-day. This value was derived from the Tseng (1977) study which investigated the relationship between peripheral circulatory disease characterized by gangrene of the extremities and the arsenic concentrations in drinking water of over 40,000 residents of Taiwan. This study established a NOAEL of 0.001 to 0.017 mg/L for blackfoot disease. The uncertainty factor used in establishing the RfD was 3, to account for the lack of data on reproductive effects and for potentially sensitive individuals in the population.

Dermal exposure to trivalent arsenic compounds (As^{3+}) could result in local hyperemia due to the corrosivity of the arsenic compound (Sittig, 1991). Arsenic trioxide and pentoxide are capable of producing skin sensitization and contact dermatitis.

To evaluate dermal exposures, an RfD based on an absorbed dose must be calculated. The oral RfD is based on the same epidemiological study that is the basis for the oral CSF, so the absorption factor of 95 percent reported by Dollarhide (1993) is applicable here. Therefore, the RfD based on an absorbed dose is 0.0003 mg/kg-day $*$ 0.95 or 0.00029 mg/kg-day.

Inhalation reference doses have not been developed for arsenic. The symptoms of chronic inhalation exposure to arsenic compounds are similar to those associated with chronic oral toxicity. Later symptoms from chronic inhalation of arsenic may include conjunctivitis, perforation of the nasal septum, skin lesions, and inflammation of the respiratory tract mucous membranes (Sittig, 1991). While not a likely exposure for the Lower Fox River and Green Bay, acute toxicity from inhalation exposure to arsenic adsorbed to particulate matter may result in conjunctivitis and pharyngitis.

5.6.7 Lead

Lead can be absorbed by the oral, inhalation, or dermal exposure routes. Once absorbed, lead is distributed to the various organs of the body, with most distribution occurring to bones, kidneys, and liver (EPA, 1984a). Placental transfer to the developing fetus is possible (Bellinger *et al.*, 1987). Inorganic lead is not known to be biotransformed within the body.

Although not applicable to the Lower Fox River and Green Bay assessment, cases of acute lead poisoning in humans are not common and have not been studied in experimental animals as thoroughly as chronic lead poisoning. Symptoms of acute lead poisoning from deliberate ingestion by humans may include vomiting, abdominal pain, hemolysis, liver damage, and reversible tubular necrosis (EPA, 1984a).

Lead and most lead chemicals are classified by the EPA as Class B2 probable human carcinogens, resulting from sufficient evidence of carcinogenicity in experimental animals and inadequate evidence of carcinogenicity in humans. The classification was a result of recent studies reporting that lead salts, primarily phosphates and acetates, administered by the oral route or by injection, produce renal tumors in rats. No quantitative estimate of cancer potency has been developed for lead compounds. EPA has also considered it inappropriate to develop an RfD since many of the health effects associated with lead intake occur essentially without a threshold (EPA, 1998c).

Subacute exposures in humans reportedly may produce a variety of neurological effects including dullness, restlessness, irritability, poor attention span, headaches, muscular tremor, hallucinations, and loss of memory. Nortier *et al.* (1980) report encephalopathy and renal damage to be the most serious complications of chronic toxicity in man and the hematopoietic system to be the most sensitive. For this reason, most data on the effects of lead exposure in humans are based upon blood lead levels. The effects of lead on the formation of hemoglobin and other hemoproteins, causing decreased levels, are reportedly detectable at lower levels of lead exposure than in any other organ system (Betts *et al.*, 1973). Peripheral nerve dysfunction is observed in adults at levels of 30 to 50 micrograms per deciliter of blood (μg/dl-blood). Children's nervous systems are reported to be affected at levels of 15 μg/dl-blood and higher (Benignus *et al.*, 1981). In high doses, lead compounds may potentially cause abortions, premature delivery, and early membrane rupture (Rom, 1976).

EPA guidance (1994b) recommends the use of the EPA Integrated Exposure Uptake/Biokinetic (IEUBK) Model for determining blood lead levels for children exposed to lead in soil, dust, and paint. The model recommends a benchmark of "either 95 percent of the sensitive population having blood lead levels below 10 micrograms per deciliter (μg/dl) or a 95 percent probability of an individual having a blood lead level below 10 μg/dl." The blood action level is not considered a threshold level below which no adverse effects are expected because of the possibility that some adverse effects may occur at lower blood levels than 10 micrograms per liter (μg/L).

The EPA Technical Review Workgroup for Lead developed a biokinetic model for non-residential adult exposure to lead in soil (EPA, 1996c). This model is a simplified representation of lead biokinetics to predict quasi-steady-state blood lead concentrations among adults who have relatively steady patterns of site exposures. The model incorporates a simplified slope factor approach, much like the model proposed by Bowers *et al.* (1994). The model assumes a baseline lead level based on average blood lead levels for adults. Media-specific ingestion and absorption parameters are assessed for the adult population, and a biokinetic slope factor that relates uptake of lead into the body to blood lead levels is estimated. Thus, adult blood lead levels are calculated based on statistical information concerning baseline exposures to lead primarily from dietary lead and an assessment of current exposure to lead in soil and dust. In addition to soil and dust exposure, the model can be applied to assess the exposure pathways of ingestion of fish and waterfowl for the Lower Fox River and Green Bay assessment (Maddaloni, 1998).

5.6.8 Mercury

Mercury has been classified by the EPA as Group D; i.e., not classifiable as to human carcinogenic potential (EPA, 1998c). The dose-response assessment for mercury, therefore, is based on non-carcinogenic health endpoints. IRIS reports verified oral reference doses for mercuric chloride and methylmercury. These values were used to evaluate inorganic and organic mercury, respectively. An inhalation RfC for elemental mercury is reported in HEAST (EPA, 1997c). This risk assessment also includes an evaluation of total mercury, which incorporates the oral RfD from methylmercury and the inhalation RfC from mercuric chloride. This was done in order to conservatively estimate health effects for mercury when the class (i.e., organic or inorganic) was unknown, and in the absence of an oral RfD for elemental mercury.

Derivation of Oral Reference Doses

Mercuric Chloride. The oral RfD for mercuric chloride is 3.0E-04 mg/kg-day (EPA, 1998c). It is based on three subchronic studies with Brown Norway rats using oral or subcutaneous dosing regimens (EPA, 1987). The target effect was autoimmune effects in the kidney. The RfD was based on a consensus opinion of a panel of mercury experts that met on October 26–27, 1987 to review issues concerning the health effects of inorganic mercury. The panel's main conclusion was that the most sensitive adverse effect for mercury was formation of mercuric ion-induced autoimmune glomerulonephritis. The results from studies in the Brown rat were determined to be the best ones available for risk assessment. Because this animal is a good surrogate for sensitive humans, the uncertainty factor should be reduced by a factor of 10 from the normal factor that would be used when based on a LOAEL in a subchronic animal study ($10 \times 10 \times 10 \times 10 = 10{,}000$). Thus, the uncertainty factor used is 1,000. EPA's confidence in the oral RfD is high. For this risk assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathway.

An acute oral Minimal Risk Level (MRL) for inorganic mercury of 0.007 mg/kg-day for renal/urinary effects was developed by ATSDR (1998b).

Methylmercury. The oral RfD for methylmercury is 1.0E-04 (EPA, 1998c). It is based on a benchmark dose in maternal hair equivalent to maternal blood and body burden levels associated with developmental neurologic abnormalities in the offspring. The data is based on effects seen in Iraq when mothers were exposed to methylmercury-treated grain in bread.

An uncertainty factor of 10 is used in deriving the RfD from the benchmark dose of 1.1 μg/kg-day. This factor is based on a factor of 3 for variability in the human population, a factor of 3 for lack of a two-generation reproductive study, and a factor of 3 for lack of data on the effect of exposure duration on developmental neurotoxicity and adult paresthesia. For this assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathway.

EPA's confidence in the RfD is medium. It should be noted, however, that there is a scientific debate concerning the appropriateness of using the Iraqi poisoning data for RfD derivation. Both reanalysis of the Iraqi data and recent data from human populations in the Seychelles Islands who consumed mercury-containing fish for long periods of time indicated that the RfD may be somewhat higher than the current EPA value (Crump *et al.*, 1995; Meyers *et al.*, 1994).

Derivation of the Inhalation Reference Dose

The Health Effects Assessment Summary Tables (EPA, 1997c) report an inhalation reference concentration for elemental mercury of 0.3 $\mu g/m^3$ for subchronic and chronic exposures. This corresponds to an RfD of 8.75E-05 mg/kg-day using the equations presented earlier for translating an RfC to an inhalation RfD. The reported value was based on several occupational studies involving exposed workers evaluated for neurotoxic effects. An uncertainty factor of 30 was applied to the concentration of 9 $\mu g/m^3$ to develop the reference concentration (EPA, 1997c). No inhalation RfCs were reported for other forms of mercury.

5.6.9 Summary of Toxicity Criteria

The EPA-derived toxicity criteria used in this risk assessment are presented in Tables 5-40 and 5-41. Table 5-40 summarizes the cancer slope factors for each chemical of potential concern, and Table 5-41 summarizes the chronic reference dose. As stated previously, chronic reference doses apply to exposure periods of 7 years or longer. In this assessment, chronic RfDs have been used to evaluate all receptors.

Three different measures of PCB concentrations are available. First, in all samples where PCBs were analyzed, a total concentration of PCBs (total PCBs) was determined (either the sum of Aroclors or the sum of congeners). Second, for a number of samples, the concentrations of individual Aroclors and other congeners are available. Therefore, the potential toxicity of PCBs was evaluated three ways. First, potential cancer and noncancer effects were evaluated based on the concentrations of total PCBs using the cancer slope factors presented in Table 5-40 (based on the values for the highest risk and persistence in Table 5-37) and the reference dose for Aroclor 1254. Second, potential cancer and noncancer effects were evaluated based on the concentrations of each Aroclor. The cancer slope factors for the lowest risk and persistence in Table 5-37 were used for Aroclor 1016, while the cancer slope factors for the highest risk and persistence in Table 5-38 were used for all other Aroclors. The RfD for Aroclor 1016 was used for this Aroclor, while the RfD for Aroclor 1254 was used for that Aroclor and Aroclors 1221, 1232, 1242, 1248, and 1260. Third, potential cancer effects were evaluated based on the concentrations of individual PCB congeners. The cancer slope factors for the individual congeners were developed by multiplying the TEFs for congeners in Table 5-38 by the cancer slope factors for 2,3,7,8-TCDD.

The cancer slope factors for individual dioxin and furan congeners were derived by applying the TEF (refer to Table 5-39) to the cancer slope factor for 2,3,7,8-TCDD. For the pesticides (dieldrin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) and arsenic, cancer slope factors were obtained directly from EPA sources as discussed previously. In addition, the reference doses for dieldrin, 4,4'-DDT, and arsenic were obtained from EPA sources as discussed previously.

The recent paper by Hurley *et al*. (1998) suggests that much of the mercury in the Lower Fox River is in an inorganic, not organic (i.e., methylmercury), form. To evaluate the influence of the different forms of mercury on its toxicity, the analysis was designed to evaluate three types of mercury: total, organic, and inorganic. For total mercury, the most conservative RfDs were chosen: the oral RfD for methylmercury and the inhalation RfD for elemental mercury. For organic mercury, the oral RfD for methylmercury was used. Since methylmercury does not have an inhalation RfD, no RfD was assigned to the inhalation pathway for organic mercury. For inorganic mercury, the oral RfD for mercuric chloride was used, while the inhalation RfD for elemental mercury was assigned to the inhalation pathway.

5.7 Baseline Risk Characterization

5.7.1 Overview

In Section 5.4, intake assumptions were formulated for each receptor, while in Section 5.5, exposure point concentrations were estimated for media that receptors may potentially contact. These intake assumptions and exposure point concentrations can be combined to generate intakes. Section 5.6 presented toxicological parameters used to estimate potential human health effects associated with chronic exposures. In this section, the intakes are combined with the toxicological parameters to estimate potential human health effects. Two types of potential health effects are evaluated: carcinogenic and non-carcinogenic. Carcinogenic effects are quantified by estimating the probability of contracting cancer based on site-related exposure. Non-carcinogenic effects are quantified by estimating a hazard index.

Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. In order to estimate the cancer risk, the intake (defined as a lifetime average daily dose, or LADD) is multiplied by the cancer slope factor:

$$Risk = LADD \cdot CSF$$

For each pathway, this calculation is performed for each chemical considered to be potentially carcinogenic, and the risks are summed to obtain the total risk due to that pathway. The total cancer risk for a particular receptor is then calculated as the sum of the risks from all exposure pathways. Wisconsin uses a risk level of 10^{-5} for evaluating cumulative cancer risks in the evaluation of sites under Chapter NR 700 while Superfund uses a risk level of 10^{-6} as the point at which risk management decisions may be considered. Risk management decisions most frequently made under Superfund are in the cancer risk range of 10^{-6} to 10^{-4}.

Potential non-carcinogenic effects were evaluated by calculating a chronic hazard index. For a single compound and intake route, the hazard quotient (HQ) is the ratio of the intake (defined as an average daily dose or ADD) to a reference dose:

$$HQ = \frac{ADD}{RfD}$$

The reference dose is a threshold dose or intake which is conservatively chosen so that if the estimated intake is less than the reference dose (i.e., the hazard index is less than 1.0), there is almost no possibility of an adverse health effect.

However, if the intake exceeds the reference dose (the hazard index exceeds 1.0), this does not indicate an adverse health effect is expected, only that a conservative threshold is exceeded. For each pathway, an HQ is derived for all appropriate chemicals. HQs for all chemicals and exposure pathways are summed to obtain the total hazard index (HI) for that receptor. The State of Wisconsin under Chapter NR 700 and EPA under Superfund both use an HI of 1.0 as a point at which risk management decisions may be considered.

A relatively large number of receptors are evaluated in a number of reaches in the Lower Fox River and Green Bay. To facilitate the computation of cancer risks and hazard indices, unit risks and unit hazard indices were calculated for each receptor and pathway by utilizing unit exposure point concentrations in the equations for calculating risks and hazard indices. For each receptor in each location, the unit risks and hazard indices were subsequently multiplied by actual concentrations to determine risks and hazard indices for that receptor in that location.

The remainder of this section presents the cancer risks and hazard indices by receptor. Unit risks and unit hazard indices for each receptor are presented in Appendix B4 along with cancer risks and noncancer hazard indices for each chemical and each exposure pathway in each location. In this section, summary tables of cancer risks and hazard indices are presented for each receptor. The summary tables for cancer risks are divided into two parts. In the first part, risks calculated using total PCB concentrations are provided along with risks for other chemicals. This part of each summary table includes risks for the following groups of chemicals:

- **Total PCBs:** the results based on the concentrations of total PCBs;
- **Total Dioxins/Furans:** the sum of the results for all dioxin and furan congeners;
- **Total Pesticides:** the sum of the results for dieldrin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT; and
- **Arsenic:** the only inorganic that is considered carcinogenic.

The second part of each table contains a focused evaluation of risks due to PCBs. Cancer risks are calculated separately for total PCB data, the Aroclor data, and the congener data.

Similarly, the tables for hazard indices are divided into two parts. In the first part, hazard indices are calculated using total PCB concentration data along with hazard indices for other chemicals. This part of each summary table includes hazard indices for the following groups of chemicals:

- **Total PCBs:** the results based on the concentrations of total PCBs;
- **Total Dioxins/Furans:** the sum of the results for all dioxin and furan congeners;
- **Total Pesticides:** the results for dieldrin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT;
- **Arsenic**; and
- **Mercury:** the results using the concentration of total mercury.

The second part of each table with hazard indices contains a focused evaluation of hazard indices due to PCBs. Hazard indices are calculated separately for total PCB data and Aroclor data.

5.7.2 Recreational Angler

Risk and Hazard Index Equations

For the recreational angler, potential exposures occur via ingestion of fish, incidental ingestion of water, dermal contact with water, and inhalation of outdoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$\begin{aligned} R_i = {} & URFfsh1\text{-}ing\text{-}c_i \cdot RF_{fishi} \cdot Cfish_{measi} \\ & + URFw2\text{-}ing\text{-}c_i \cdot C_{sw-ti} \\ & + URFw2\text{-}d\text{-}c_i \cdot C_{sw-di} \\ & + URFa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw-di} \end{aligned}$$

where:

R_i	=	cancer risk for chemical *i*,
$URFfsh1\text{-}ing\text{-}c_i$	=	unit risk factor for chemical *i* for ingestion of fish (kg/mg),
Rf_{fishi}	=	reduction factor for chemical *i* for fish (milligrams per milligram [mg/mg]),
$Cfish_{measi}$	=	measured concentration of chemical *i* in fish (mg/kg),
$URFw2\text{-}ing\text{-}c_i$	=	unit risk factor for chemical *i* for incidental ingestion of surface water (liters per milligram [L/mg]),
C_{sw-ti}	=	measured total concentration of chemical *i* in water (mg/L),

$URFw2\text{-}d\text{-}c_i$	=	unit risk factor for chemical *i* for dermal contact with surface water (L/mg),
$C_{sw\text{-}di}$	=	measured dissolved concentration for chemical *i* in water (mg/L),
$URFa2\text{-}inh\text{-}c_i$	=	unit risk factor for chemical *i* for inhalation of outdoor air (cubic meters per milligram [m^3/mg]), and
Tf_{swoai}	=	transfer factor for volatilization from surface water to outdoor air (liters per cubic meter [L/m^3]).

The total risk for all chemicals is obtained by summing the individuals values of R_i for each chemical.

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i = {} & UHIfsh1\text{-}ing\text{-}c_i \cdot RF_{fishi} \cdot Cfish_{measi} \\ & + UHIw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} \\ & + UHIw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + UHIa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \end{aligned}$$

The variables in this equation have been defined previously except:

Hi_i	=	hazard index for chemical *i*,
$UHIfsh1\text{-}ing\text{-}c_i$	=	unit hazard index for chemical *i* for ingestion of fish (kg/mg),
$UHIw2\text{-}ing\text{-}c_i$	=	unit hazard index for chemical *i* for incidental ingestion of surface water (L/mg),
$UHIw2\text{-}d\text{-}c_i$	=	unit hazard index for chemical *i* for dermal contact with surface water (L/mg), and
$UHIa2\text{-}inh\text{-}c_i$	=	unit hazard index for chemical *i* for inhalation of outdoor air (m^3/mg).

The unit risks and hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations and reduction factors were discussed previously.

Cancer Risks and Hazard Indices

Table 5-42 presents the cancer risks for the recreational angler using reasonable maximum exposure (RME) assumptions and upper-bound exposure point concentrations, while Table 5-43 presents the chronic hazard indices for this same receptor. Tables 5-44 and 5-45 present the cancer risks and chronic hazard indices for the recreational angler using RME assumptions and average exposure point concentrations. Tables 5-46 and 5-47 present the cancer risks and chronic hazard indices for the recreational angler using central tendency exposure (CTE) assumptions and average exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for the various exposure assumptions.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
RME with Average Concentrations	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
CTE with Average Concentrations	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
Hazard Indices					
RME with Upper-bound Concentrations	76.2	107.1	17.9	59.8	55.9
RME with Average Concentrations	59.1	83.9	14.6	52.8	53.2
CTE with Average Concentrations	15.0	21.3	3.7	13.4	13.5

The results above indicate that cancer risks for the recreational angler exceed a risk of 1.0×10^{-6} for all areas under all exposure scenarios. The results by pathway (Tables 5-42, 5-44, and 5-46) indicate that in each case, the cancer risk for the fish ingestion pathway comprises essentially 100 percent of the total risk, and that total PCBs are the driving chemical, being responsible for over 80 percent of the risk in each reach in the Lower Fox River and over 70 percent of the risk in Green Bay. In addition, the hazard indices for each reach and exposure scenario exceed 1.0. As with the results for cancer risks, the fish ingestion pathway comprises essentially 100 percent of the total hazard index, and total PCBs are the driving chemical (refer to Tables 5-43, 5-45, and 5-47).

5.7.3 High-intake Fish Consumer

Risk and Hazard Index Equations

For the high-intake fish consumer, potential exposures occur via ingestion of fish, incidental ingestion of water, dermal contact with water, and inhalation of outdoor air. The equations used to calculate cancer risks and hazard indices for this receptor are identical to those presented above for the recreational angler.

The unit risks and unit hazard indices for the high-intake fish consumer are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations and reduction factors were discussed previously.

Cancer Risks and Hazard Indices

Table 5-48 presents the cancer risks for the high-intake fish consumer using RME assumptions and upper-bound exposure point concentrations, while Table 5-49 presents the chronic hazard indices for this same receptor. Tables 5-50 and 5-51 present the cancer risks and chronic hazard indices for the high-intake fish consumer using RME assumptions and average exposure point concentrations. Tables 5-52 and 5-53 present the cancer risks and chronic hazard indices for the high-intake fish consumer using CTE assumptions and average exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for the various exposure assumptions.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
RME with Average Concentrations	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
CTE with Average Concentrations	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Hazard Indices					
RME with Upper-bound Concentrations	104.3	146.8	24.5	82.0	86.6
RME with Average Concentrations	80.9	114.9	20.0	72.4	72.8
CTE with Average Concentrations	21.2	30.1	5.2	18.9	19.0

The results above indicate that cancer risks for the high-intake fish consumer exceed a risk of 1.0×10^{-6} for all areas under all exposure scenarios. The results by pathway (Tables 5-48, 5-50, and 5-52) indicate that in each case, the cancer risk for the fish ingestion pathway comprises essentially 100 percent of the total risk, and that total PCBs are the driving chemical, being responsible for over 80 percent of the risk in each reach in the Lower Fox River and over 70 percent of the risk in Green Bay. In addition, the hazard indices for each area and exposure scenario exceed 1.0. As with the results for cancer risks, the fish ingestion pathway comprises essentially 100 percent of the total hazard index, and total PCBs are the driving chemical (refer to Tables 5-49, 5-51, and 5-53).

5.7.4 Hunter

Risk and Hazard Index Equations

For the hunter, potential exposures occur via ingestion of waterfowl, incidental ingestion of water, dermal contact with water, and inhalation of outdoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$\begin{aligned} R_i = {} & URFfd1\text{-}ing\text{-}c_i \cdot RF_{WF_i} \cdot CWF_{measi} \\ & + URFw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} \\ & + URFw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + URFa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \end{aligned}$$

The variables in this equation have been defined previously except:

$URFfd1\text{-}ing\text{-}c_i$ = unit risk factor for chemical *i* for ingestion of waterfowl (kg/mg),
RF_{WFi} = reduction factor for chemical *i* for waterfowl (mg/mg), and
CWF_{measi} = measured concentration of chemical *i* in waterfowl (mg/kg).

The total risk for all chemicals is obtained by summing the individuals values of R_i for each chemical.

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i = {} & UHIfd1\text{-}ing\text{-}c_i \cdot RF_{WF_i} \cdot CWF_{measi} \\ & + UHIw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} \\ & + UHIw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + UHIa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \end{aligned}$$

The variables in this equation have been defined previously except:

$UHIfd1\text{-}ing\text{-}c_i$ = unit hazard index for chemical *i* for ingestion of waterfowl (kg/mg)

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations and reduction factors were discussed previously.

Cancer Risks and Hazard Indices

Table 5-54 presents the cancer risks for the hunter using RME assumptions and upper-bound exposure point concentrations, while Table 5-55 presents the chronic hazard indices for this same receptor. Tables 5-56 and 5-57 present the cancer risks and chronic hazard indices for the hunter using RME assumptions and average exposure point concentrations. Tables 5-58 and 5-59 present the cancer risks and chronic hazard indices for the hunter using CTE assumptions and average exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for the various exposure assumptions.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
RME with Average Concentrations	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
CTE with Average Concentrations	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Hazard Indices					
RME with Upper-bound Concentrations	1.7	2.0	3.1	2.0	2.1
RME with Average Concentrations	0.94	1.3	1.1	0.59	0.84
CTE with Average Concentrations	0.47	0.66	0.57	0.30	0.42

The results above indicate that cancer risks for the hunter exceed a risk of 1.0×10^{-6} for all areas and scenarios with the upper-bound and average concentrations (Tables 5-54 and 5-56). The results by pathway (Tables 5-54, 5-56, and 5-58) indicate that in each case, the cancer risk for the waterfowl ingestion pathway comprises nearly 100 percent of the total risk, and that total PCBs are commonly the driving chemical, being responsible for over 73 percent of the risk in each reach in the Lower Fox River and over 74 percent of the risk in Green Bay.

The hazard indices for several reaches exceed 1.0 under the two RME scenarios; however, the hazard indices are only slightly above this value. In addition, for the CTE scenario, all hazard indices are below 1.0. As with the results for cancer risks, the waterfowl ingestion pathway comprises over 96 percent of the total hazard index and total PCBs are the driving chemical (refer to Tables 5-55, 5-57, and 5-59).

5.7.5 Drinking Water User

Risk and Hazard Index Equations

For the drinking water user, potential exposures occur via ingestion of water, dermal contact with water, and inhalation of indoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$\begin{aligned} R_i &= URFw1\text{-}ing\text{-}c_i \cdot C_{sw-ti} + URFw2\text{-}ing\text{-}c_i \cdot C_{sw-ti} \\ &+ URFw1\text{-}d\text{-}c_i \cdot C_{sw-di} + URFw2\text{-}d\text{-}c_i \cdot C_{sw-di} \\ &+ URFw1av\text{-}inh\text{-}c_i \cdot TF_{bwai} \cdot C_{sw-di} + URFw2av\text{-}inh\text{-}c_i \cdot TF_{shi} \cdot C_{sw-di} \end{aligned}$$

The variables in this equation have been defined previously except:

$URFw1\text{-}ing\text{-}c_i$	=	unit risk factor for chemical *i* for incidental ingestion of surface water by a young child (L/mg),
$URFw1\text{-}d\text{-}c_i$	=	unit risk factor for chemical *i* for dermal contact with surface water by a young child (L/mg),
$URFw1av\text{-}inh\text{-}c_i$	=	unit risk factor for chemical *i* for inhalation of indoor air by a young child (m^3/mg),
Tf_{bwai}	=	transfer factor for chemical *i* for volatilization from bath water to air (L/m^3),
$URFw2av\text{-}inh\text{-}c_i$	=	unit risk factor for chemical *i* for inhalation of indoor air by an adult (m^3/mg), and
Tf_{shi}	=	transfer factor for chemical *i* for volatilization from shower water to air (L/m^3).

The total risk for all chemicals is obtained by summing the individual values of R_i for each chemical.

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i &= UHIw1\text{-}ing\text{-}c_i \cdot C_{sw-ti} + UHIw2\text{-}ing\text{-}c_i \cdot C_{sw-ti} \\ &+ UHIw1\text{-}d\text{-}c_i \cdot C_{sw-di} + UHIw2\text{-}d\text{-}c_i \cdot C_{sw-di} \\ &+ UHIw1av\text{-}inh\text{-}c_i \cdot TF_{bwai} \cdot C_{sw-di} + UHIw2av\text{-}inh\text{-}c_i \cdot TF_{shi} \cdot C_{sw-di} \end{aligned}$$

The variables in this equation have been defined previously except:

$UHIw1\text{-}ing\text{-}c_i$	=	unit hazard index for chemical *i* for incidental ingestion of surface water by a young child (L/mg),

$UHIw1\text{-}d\text{-}c_i$ = unit hazard index for chemical *i* for dermal contact with surface water by a young child (L/mg),

$UHIw1av\text{-}inh\text{-}c_i$ = unit hazard index for chemical *i* for inhalation of indoor air by a young child (m^3/mg), and

$UHIw2av\text{-}inh\text{-}c_i$ = unit hazard index for chemical i for inhalation of indoor air by an adult (m^3/mg).

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-60 presents the cancer risks for the drinking water user using RME assumptions and upper-bound exposure point concentrations, while Table 5-61 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.2E-08
Hazard Indices					
RME with Upper-bound Concentrations	3.6	0.10	3.2	0.33	0.19

The results above indicate that cancer risks for the drinking water user are below a risk of 1.0×10^{-6} for all areas except the De Pere to Green Bay Reach. The results by pathway (Table 5-60) indicate that for each area, the cancer risk for the direct contact with surface water pathways (ingestion and dermal contact) comprise over 97 percent of the total risk. Total PCBs are the driving chemical for all areas except the De Pere to Green Bay Reach, being responsible for essentially 100 percent of the risk in each area. For the De Pere to Green Bay Reach, arsenic is the driving chemical, contributing over 98 percent of the overall risk. It should be noted that arsenic was detected in only one surface water sample out of four samples collected from this reach, and this was the only sample with detected levels of arsenic in the seven samples from the Lower Fox River. Therefore, the exposure point concentration was based on this single detection of arsenic, and may be overly conservative. Finally, it should also be noted that water from this reach of the Lower Fox River is not used for drinking water.

The hazard indices for two reaches slightly exceed 1.0, while the other two reaches and Green Bay are below this level. As with the results for cancer risks, the direct contact with surface water pathways comprise the majority of the total hazard index. Total PCBs are the driving chemical in the Appleton to Little Rapids Reach (55 percent), while arsenic contributes the most in the De Pere to Green Bay Reach (47 percent), and the other areas are driven by mercury (over 92 percent) (refer to Table 5-61).

Hazard indices above 1.0 in the Little Lake Butte des Morts Reach and the Little Rapids to De Pere Reach are due to mercury. However, the exposure point concentrations for mercury in surface water are based on limited data from the past 10 years. These data include water samples for a variety of permits that utilized generalized methods for mercury analysis, not analytical methods targeted specifically to quantitate mercury concentrations at low levels. A recent study by Hurley *et al.* (1998) presented the results of surface water and sediment sampling that was targeted specifically at mercury in the Lower Fox River and utilized analytical methods that allowed low concentrations of mercury to be quantitated. The study by Hurley *et al.* (1998) measured water concentrations at several locations in the Lower Fox River over time. Samples collected between 1994 and 1996 from several locations along the Lower Fox River indicated a range of total mercury concentrations from 0.0018 to 0.182 μg/L, with an average concentration of 0.0292 μg/L. In contrast, the detected total mercury concentrations included in the Lower Fox River database used in this risk assessment ranged from 0.0002 to 7.14 μg/L with an average of 3.4 μg/L. Since the mercury data from the study by Hurley *et al.* (1998) is more comprehensive than the data assembled for the Lower Fox River database and the data of Hurley *et al.* (1998) was collected to specifically measure mercury at low concentrations, an additional evaluation of the hazard indices to the drinking water user has been conducted, utilizing the maximum detected concentration of mercury in the Lower Fox River from the more recent data from Hurley *et al.* (1998) as a cap to the exposure point concentration in each area. If the exposure point concentration exceeded the 0.182 μg/L measured by Hurley *et al.* (1998), then this value was included in the hazard index calculation. This was done for dissolved mercury concentrations as well as total concentrations, which is quite conservative because the data from Hurley *et al.* (1998) indicate dissolved concentrations remain somewhat constant around 0.001 μg/L.

The results based on the mercury data from Hurley *et al*. (1998) are presented in Table 5-62 and are summarized below. The first row restates the total hazard indices calculated with the data from the Lower Fox River database while the second row presents the total hazard indices calculated with mercury data from Hurley *et al.* (1998).

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Hazard Indices					
RME with Upper-bound Concentrations	3.6	0.10	3.2	0.33	0.19
RME with Upper-bound Concentrations and Recent Mercury Data	0.18	0.10	0.16	0.33	0.19

The hazard indices for the drinking water user are below 1.0 when incorporating the more recent mercury data from Hurley *et al.* (1998).

5.7.6 Local Resident

Risk and Hazard Index Equations

For the local resident, potential exposures occur via inhalation of outdoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$R_i = URFa1{-}inh{-}c_i \cdot TF_{swoai} \cdot C_{sw-di} + URFa2{-}inh{-}c_i \cdot TF_{swoai} \cdot C_{sw-di}$$

The variables in this equation have been defined previously except:

$URFa1\text{-}inh\text{-}c_i$ = unit risk factor for chemical *i* for inhalation of outdoor air by a young child (m^3/mg)

The equation used to calculate hazard indices is:

$$HI_i = UHIa1{-}inh{-}c_i \cdot TF_{swoai} \cdot C_{sw-di} + UHIa2{-}inh{-}c_i \cdot TF_{swoai} \cdot C_{sw-di}$$

The variables in this equation have been defined previously except:

$UHIa1\text{-}inh\text{-}c_i$ = unit hazard index for chemical *i* for inhalation of outdoor air by a young child (m^3/mg)

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-63 presents the cancer risks for the local resident using RME assumptions and upper-bound exposure point concentrations, while Table 5-64 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Hazard Indices					
RME with Upper-bound Concentrations	3.8	0.043	1.2	0.004	0.24

The results above indicate that cancer risks for the local resident are well below a risk of 1.0×10^{-6} for all areas. Inhalation of volatiles in outdoor air is the only applicable pathway for this receptor, and total PCBs are the only carcinogenic volatile constituents present in outdoor air (refer to Table 5-63). Similarly, total mercury is the only volatile constituent present in outdoor air having an inhalation reference dose. The hazard indices for the Appleton to Little Rapids Reach, De Pere to Green Bay Reach, and for Green Bay are below the target hazard index of 1.0, while the hazard indices for the local resident in the other areas slightly exceed 1.0 (refer to Table 5-64).

Elevated hazard indices for the Little Lake Butte des Morts Reach, the Little Rapids to De Pere Reach, and Green Bay are due to mercury. However, as discussed in Section 5.7.5, the concentrations of mercury in surface water used in the exposure calculations are based on limited data from the past 10 years. Therefore, an additional evaluation of the hazard indices to the local resident has been conducted, utilizing the maximum detected concentration of mercury in the Lower Fox River from the more recent and comprehensive study by Hurley *et al.* (1998) to cap the surface water concentrations of each area. If the dissolved or total concentration of mercury exceeded the maximum total concentration of mercury of 0.182 μg/L measured by Hurley *et al.* (1998), then this value was used as the surface water concentration and the hazard indices were recalculated.

The results based on the more recent mercury data are presented in Table 5-65 and are summarized below. The first row restates the total hazard indices calculated with the data from the Lower Fox River database while the second row presents the total hazard indices calculated with mercury data from Hurley *et al.* (1998).

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Hazard Indices					
RME with Upper-bound Concentrations	3.8	0.043	1.2	0.004	0.24
RME with Upper-bound Concentrations and Recent Mercury Data	0.097	0.043	0.086	0.004	0.24

The hazard indices for the local resident are below 1.0 when incorporating the more recent mercury data from Hurley *et al.* (1998).

5.7.7 Recreational Water User

Risk and Hazard Index Equations

For both recreational water users (swimmer and wader), potential exposures occur via incidental ingestion of water, dermal contact with water, inhalation of outdoor air, ingestion of sediment, and dermal contact with sediment or sediment pore water. Assuming dermal contact with sediment, the equation used to calculate risks for this receptor for chemical i is:

$$\begin{aligned} R_i = {} & URFw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} + URFw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + URFa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \\ & + URFsd1\text{-}ing\text{-}c_i \cdot C_{sedi} + URFsd1\text{-}d\text{-}c_i \cdot C_{sedi} \end{aligned}$$

The variables in this equation have been defined previously except:

$URFsd1\text{-}ing\text{-}c_i$ = unit risk factor for chemical i for ingestion of sediment (kg/mg), and

$URFsd1\text{-}d\text{-}c_i$ = unit risk factor for chemical i for dermal contact with sediment (kg/mg).

Assuming dermal contact with sediment pore water, the equation used to calculate risks for chemical i is the same as that above with the exception of the final expression, which is replaced by

$$URFw3{-}d{-}c_i \cdot TF_{sdpwi} \cdot C_{sedi}$$

where:

$URFw3\text{-}d\text{-}c_i$	=	unit risk factor for chemical i for dermal contact with sediment pore water (L/mg), and
Tf_{sdpwi}	=	transfer factor for chemical i for sediment to pore water (kilograms per liter [kg/L]).

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i = {} & UHIw2{-}ing{-}c_i \cdot C_{sw-ti} + UHIw2{-}d{-}c_i \cdot C_{sw-di} \\ & + UHIa2{-}inh{-}c_i \cdot TF_{swoai} \cdot C_{sw-di} \\ & + UHIsd1{-}ing{-}c_i \cdot C_{sedi} + UHIsd1{-}d{-}c_i \cdot C_{sedi} \end{aligned}$$

The variables in this equation have been defined previously except:

$UHIsd1\text{-}ing\text{-}c_i$	=	unit hazard index factor for chemical i for ingestion of sediment (kg/mg), and
$UHIsd1\text{-}d\text{-}c_i$	=	unit hazard index for chemical i for dermal contact with sediment (kg/mg).

As indicated above for the cancer risk equation, the final expression in the above equation is replaced if dermal contact with sediment pore water is evaluated rather than dermal contact with sediment, as follows:

$$UHIw3{-}d{-}c_i \cdot TF_{sdpwi} \cdot C_{sedi}$$

where:

$UHIw3\text{-}d\text{-}c_i$	=	unit hazard index for chemical i for dermal contact with sediment pore water (L/mg)

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-66 presents the cancer risks for the swimmer (recreational water user) using RME assumptions and upper-bound exposure point concentrations, while Table 5-67 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.2E-07	7.3E-08	8.1E-08	2.0E-07	5.2E-08
Hazard Indices					
RME with Upper-bound Concentrations	0.059	0.008	0.022	0.015	0.004

The results above indicate that cancer risks for the swimmer are well below a risk of 1.0×10^{-6} for all areas. The results by pathway (Table 5-66) indicate that the cancer risk for the direct contact with sediment pathways (incidental ingestion and dermal contact) comprise the majority of the total risk for all reaches in the Lower Fox River (between 65 and 91 percent) and for Green Bay (92 percent). Arsenic is the driving chemical for the De Pere to Green Bay Reach and Green Bay, being responsible for 58 and 86 percent of the total risk in each area. In the other reaches, total PCBs drives the risk, comprising from 64 to 77 percent of the total risk.

The results above also indicate that hazard indices for the swimmer are well below 1.0 for all reaches. The results by pathway (Table 5-67) indicate that the hazard indices for the direct contact with surface water pathways (incidental ingestion and dermal contact) comprise the majority of the total hazard index for the De Pere to Green Bay Reach (71 percent). The hazard indices for the direct contact with sediment pathways (incidental ingestion and dermal contact) comprise the majority of the total hazard index for the Appleton to Little Rapids and Little Rapids to De Pere reaches (74 and 44 percent). The volatile inhalation pathway comprises the majority of the hazard index for the Little Lake Butte des Morts Reach and Green Bay (55 and 45 percent). Total PCBs are the driving chemicals for the Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay reaches, being responsible for between 63 and 96 percent of the total hazard index in each area. The remaining areas are driven by mercury (50 to 59 percent).

Tables 5-68 and 5-69 present the cancer risks and chronic hazard indices for the wader (recreational water user), also using RME assumptions and upper-bound exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	5.0E-07	9.9E-08	1.1E-07	2.5E-07	7.4E-08
Hazard Indices					
RME with Upper-bound Concentrations	0.11	0.010	0.019	0.022	0.003

The results above indicate that cancer risks for the wader are well below a risk of 1.0×10^{-6} for all areas. The results by pathway (Table 5-68) indicate that for all areas, the cancer risk for the direct contact with sediment pathways comprise over 97 percent of the total risk. For the wader, arsenic is the driving chemical for the De Pere to Green Bay Reach and Green Bay, being responsible for 63 and 90 percent, respectively, of the total risk. For the other reaches, total PCBs drive the risk, comprising between 69 and 84 percent of the total risk.

The results above also indicate that hazard indices for the wader are well below 1.0 for all areas. The results by pathway (Table 5-69) indicate that for all areas, the hazard indices for the direct contact with sediment pathways comprise 83 percent or more of the total hazard index. Total PCBs is the driving chemical for all areas, being responsible for 54 to 97 percent of the total hazard index in each area.

5.7.8 Marine Construction Worker

Risk and Hazard Index Equations

For the marine construction worker, potential exposures occur via incidental ingestion of water, dermal contact with water, inhalation of outdoor air, ingestion of sediment, and dermal contact with sediment. The equations used to calculate risks and hazard indices are identical to those presented above for the recreational water user (not including the option for dermal contact with sediment pore water).

The unit risks are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-70 presents the cancer risks for the marine construction worker using RME assumptions and upper-bound exposure point concentrations, while Table 5-71 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	1.5E-06	2.2E-07	2.8E-07	5.5E-07	1.5E-07
Hazard Indices					
RME with Upper-bound Concentrations	0.27	0.011	0.065	0.018	0.012

The results above indicate that cancer risks for the marine construction worker are below a risk of 1.0×10^{-6} for all but two areas. The calculated cancer risks slightly exceed the 10^{-6} level in the Little Lake Butte des Morts and Appleton to Little Rapids reaches. The results by pathway (Table 5-70) indicate that for each area, the cancer risk for the direct contact with sediment pathways (incidental ingestion and dermal contact) comprise over 96 percent of the total risk. Total PCBs are the driving chemical for the Little Lake Butte des Morts Reach, the Little Rapids to De Pere Reach, and the Appleton to Little Rapids Reach, being responsible for 74 to 88 percent of the total risk in each area. In the De Pere to Green Bay Reach and Green Bay, arsenic drives the risk with 53 and 85 percent of the total.

Hazard indices for each reach and for Green Bay are well below 1.0. The direct contact with sediment pathways comprise the majority (50 to 97 percent) of the total hazard index for the Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay reaches. For the other areas, the volatile inhalation pathway comprises the majority of the hazard index (60 to 75 percent). Total PCBs are the driving chemicals for the Appleton to Little Rapids and De Pere to Green Bay reaches, comprising 94 and 86 percent of the total hazard index for each area (refer to Table 5-71). Mercury is the driving chemical for the Little Lake Butte des Morts Reach, Little Rapids to De Pere Reach, and Green Bay, contributing 52 to 79 percent of the total hazard index.

5.7.9 Summary of Cancer Risks and Hazard Indices

In order to provide a comparison among all receptors and all reaches of the Lower Fox River and Green Bay, summary tables of the cancer risks and hazard indices have been included as Tables 5-72 and 5-73, respectively. This information is also presented graphically (by area) in Figures 5-2 through 5-11.

Cancer risks exceeding 1.0×10^{-6} were identified for the recreational anglers, high-intake fish consumers, hunters, and drinking water users. Cancer risks for the marine construction worker slightly exceed the 1.0×10^{-6} level in the Little Lake Butte des Morts Reach. Cancer risks as high as 3.8×10^{-3} were calculated for high-intake fish consumers, while risks as high as 2.8×10^{-3} were calculated for recreational anglers. There are relatively small differences in the RME risks between these two populations. These values are 45 and 34 times greater than the next highest risks calculated for any other receptor; the receptor with the next highest risks being the hunter with a risk of 8.3×10^{-5}. For the recreational anglers and high-intake fish consumers, the cancer risks are driven by the ingestion of PCBs in fish tissue (over 80 percent for reaches of the Lower Fox River and over 68 percent in Green Bay). For the hunters, the cancer risks are driven by the ingestion of PCBs in waterfowl tissue. The risks to drinking water users exceed the 10^{-6} level only in the De Pere to Green Bay Reach (3.8×10^{-5}). This exceedance is due to arsenic, and the arsenic concentration used in the calculation is the value detected in one of four water samples from this reach. Arsenic was detected only once in the seven samples collected from the Lower Fox River, so it is quite possible that actual arsenic concentrations are lower than those used in this analysis; therefore, the risks associated with arsenic in this reach may be overstated. Additionally, the water in this reach is not currently used as a source of drinking water and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water).

Noncancer hazard indices exceeding 1.0, which indicate the potential for adverse effects, have been identified for the recreational anglers, high-intake fish consumers, hunters, drinking water users, and local residents. While the hazard indices for the hunter, drinking water user, and local resident exceed 1.0, the maximum calculated hazard index for these receptors was 3.8, only slightly above 1.0. In comparison, hazard indices for the high-intake fish consumers and recreational anglers reach maximum values of 147 and 107, respectively, more than two orders of magnitude above 1.0. As found for cancer risks, there are not large differences in the maximum hazard indices between the two populations of fish consumers. Exposure to PCBs in fish is responsible for over 86 percent of the hazard index for recreational anglers and high-intake fish consumers in the Lower Fox River and over 88 percent of the hazard index for recreational anglers and high-intake fish consumers in Green Bay. For the hunter, PCBs are responsible for over 95 percent of the total hazard index in the Lower Fox River and over 91 percent of the total hazard index in Green Bay.

Noncancer hazard indices exceeding 1.0 for the drinking water user and local resident are due to mercury. The mercury surface water concentrations in the

Lower Fox River database were obtained from a variety of sources that did not necessarily use analytical methods intended to quantitate low concentrations of this chemical. The study by Hurley *et al.* (1998) measured dissolved and total mercury in surface water from several locations on the Lower Fox River with much finer temporal resolution than the data included in the Fox River database. When using more recent mercury data in the hazard index calculations for the drinking water user and local resident, the resulting hazard indices were below 1.0.

EPA guidance for risk characterization (EPA, 1995b, 1995c) indicates that an important step in the risk characterization process is the identification of subpopulations that may be highly exposed or highly susceptible. This evaluation of cancer risks and noncancer hazard indices indicates that the receptors with the highest risks and hazard indices are recreational anglers and high-intake fish consumers. Since calculated cancer risks exceed the 10^{-6} level by more than three orders of magnitude and calculated hazard indices exceed 1.0 by up to two orders of magnitude, the number of people included in these subpopulations is important to consider.

As was previously noted in Section 5.4.3, there are approximately 136,000 individuals with fishing licenses (WDNR, 1999d) living in communities adjacent to the Lower Fox River and Green Bay. The entire population of this area is estimated to be on the order of 640,000 (Census Bureau, 1992), which indicates that as many as 21 percent of the residents are active anglers. The most highly exposed recreational anglers are estimated to be about 10 percent (greater than the upper 90th percentile) of the licensed angler population, or about 14,000 anglers. In addition to licensed anglers, their family members (who may not be licensed anglers) can be exposed to PCBs in fish. The population of high-intake fish consumers, the most highly exposed subpopulation evaluated in this risk assessment, includes about 3,800 persons considered low-income minority anglers, 1,200 Hmong anglers residing in the Green Bay area, and 6,800 Oneida living in the Lower Fox River, Green Bay, and Milwaukee areas. For the recreational anglers and high-intake fish consumers, the exposure route of primary concern is ingestion of fish containing PCBs. The calculated cancer risks were as high as 2.8×10^{-3} for the recreational angler and 3.8×10^{-3} for the high-intake fish consumer. This is about three orders of magnitude above the risk level of 10^{-6}. Put differently, this represents a chance of approximately four in 1,000 that an individual could contract cancer in their lifetime as a result of consuming fish caught from the Lower Fox River or Green Bay. This estimate is actually an upper 95 percent confidence limit of the probability, and the actual risks may be much lower.

The calculated hazard indices were as high as 107 for the recreational angler and 147 for the high-intake fish consumer, again not showing large differences between these two groups. As discussed in Section 5.6.2, the noncancer health effects associated with exposure to PCBs include reproductive effects (e.g., conception failure in highly-exposed women [Courval *et al.*, 1997]), developmental effects (e.g., neurological impairments in highly-exposed infants and children [Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996]), and immune system suppression (e.g., increased incidence of infectious disease in highly-exposed infants [Smith, 1984; Humphrey, 1988], effects on T-cell counts in adults and infants [Tryphonas, 1995; Weisglas-Kuperus *et al.*, 1995] or the possibility of increased susceptibility to infectious diseases in children exposed prenatally to PCBs and dioxins [Weisglas-Kuperus *et al.*, 2000]). All of these noncancer health effects are extensively documented in animal studies (ATSDR, 1997).

Population estimates for hunters are more difficult to define. The Wisconsin Department of Natural Resources estimated that there are approximately 3,000 individuals in Brown County with licenses to hunt waterfowl. Brown County includes the city of Green Bay and has a population of about 200,000 people (Census Bureau, 1992). Assuming that the same ratio of licenses to people applies elsewhere in the Green Bay to Lake Winnebago corridor where the overall population is 640,000 people, the number of individuals licensed to hunt waterfowl in the Lower Fox River/Green Bay area is about 9,600 people. For the hunter, the exposure route of primary concern is the ingestion of waterfowl containing PCBs. The calculated risks for this receptor were as high as 8.3×10^{-5}, slightly less than two orders of magnitude above the risk level of 10^{-6}. This represents a chance of one in 10,000 that an individual could contract cancer as a result of consuming hunted waterfowl. The hazard indices were as high as 3.1, which is about three times greater than the value of 1.0. The noncancer health effects associated with exposure to PCBs for the hunter are similar to those described previously for recreational and high-intake fish consumers.

The angling subpopulations (recreational anglers and high-intake fish consumers) have been identified as the most highly-exposed receptor populations. In addition, the elevated cancer risks and noncancer hazard indices are attributable mainly to PCB exposure via fish ingestion. Consequently, to further evaluate these subgroups, a focused evaluation of exposure to PCBs in fish by recreational anglers and high-intake fish consumers is presented in Section 5.9.

5.8 Evaluation of Lead

Based on an evaluation of data available at the time, lead was identified as a chemical of potential concern in the Screening Level Risk Assessment (RETEC, 1998b). Since then, more data from the Lower Fox River and Green Bay, as well as background and reference data, have become available. This section will provide an evaluation of all existing lead data to determine whether or not lead is likely to pose a significant risk to human health.

5.8.1 Sediment

Several surface sediment samples were analyzed for lead from the Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay reaches. In addition, samples from background and reference locations (including Lake Winnebago) were analyzed for lead. Table 5-74 summarizes the lead data for surface sediment samples.

The human health screening criteria for contact with lead used in the Screening Level Risk Assessment (RETEC, 1998b) was the value for residential soil of 400 mg/kg (EPA, 1996e). Little Lake Butte des Morts and Little Rapids to De Pere were the only reaches which contain a maximum lead concentration exceeding this screening value. For the Little Rapids to De Pere Reach, the maximum detected concentration of lead was 1,400 mg/kg. The next highest detection in this area is 297 mg/kg, which is well below the screening value. The average lead concentration in surface sediments from the Little Rapids to De Pere Reach was 159 mg/kg, also well below the screening value. For the Little Lake Butte des Morts Reach, three out of 27 samples exceeded the 400 mg/kg screening value. However, the maximum detected concentration of lead was 522 mg/kg, only slightly above the screening value. The average lead concentration in surface sediments from the Little Lake Butte des Morts Reach was 171 mg/kg, well below the screening value.

Based on these results, it is unlikely that the lead concentrations detected in sediments from the Lower Fox River would pose a direct contact risk to human health. Only four samples out of 157 on-site surface sediment samples contained concentrations exceeding the screening value. In addition, this screening value is conservative in that it is protective of daily soil contact by a young child in a residential setting. Exposure to sediments of the Lower Fox River is significantly less than residential soil exposure. Therefore, no further evaluation of direct contact exposure to lead in sediments is warranted for the human health risk assessment.

5.8.2 Surface Water

A number of surface water samples have been collected from the Lower Fox River and from intakes at several of the industries along the river. Both filtered and unfiltered data are available for the river samples, while only unfiltered samples are available for the intake samples. Lead was detected in each sample collected at concentrations ranging from non-detect to 5.3 μg/L (the maximum concentration from the filtered samples was 0.124 μg/L).

A comparison of the detected concentrations to the screening criteria available for lead in surface water indicate that lead is not present in concentrations that might pose a risk to human health. The action level for lead in water is 15 μg/L (EPA, 2000b) and is intended to be protective of individuals (including young children) who drink the water on a daily basis. EPA (1993b) also provides an ambient water quality criterion of 50 μg/L for human health. The maximum concentrations in both filtered and unfiltered water samples are below each of these screening criteria. Although water from the Lower Fox River is not routinely used as a drinking water source, these data indicate that such use of the water would not result in unacceptable exposure to lead. Therefore, no further evaluation of direct exposure to lead in surface water is warranted for the human health risk assessment.

5.8.3 Fish Tissue

Several fish tissue samples were analyzed for lead from the Little Lake Butte des Morts and De Pere to Green Bay reaches, and from Green Bay. The majority of these were whole fish samples, but a small percentage of fillet samples were available as well. Samples were collected between 1977 and 1986 and included a wide variety of fish species and types (e.g., bottom feeders, predators, pelagic fish).

The analyses consistently report a detection limit of 5 mg/kg (with one exception of 0.5 mg/kg). Out of 111 samples, eight (or 7.2 percent) were reported as detections; however, every one of these detections was also equal to 5 mg/kg. Essentially, lead was not detected in any of the fish tissue samples at a concentration above the reporting limit. This is not an unusual finding, as the detected concentrations in both sediment and surface water were relatively low, and lead does not significantly bioaccumulate. For these reasons, no further evaluation of lead in fish tissue is warranted for the human health risk assessment.

5.8.4 Waterfowl Tissue

In 1984, 12 tissue (muscle) samples from a variety of waterfowl were collected and analyzed for lead. These samples were collected from locations near Little

Lake Butte des Morts, Green Bay, and reference locations (including Dunbar and Navarino Wildlife Areas). Lead was not detected in any of these samples, which all reported detection limits of 5 mg/kg. In 1996, 10 tissue samples (of unknown type) from Canada geese were collected from the Green Bay area and various other reference locations (including Milwaukee and Hurakon). Lead was detected in the Green Bay samples at concentrations ranging from 0.05 to 0.09 mg/kg. The concentrations of lead in the reference location samples ranged from 0.03 to 0.13 mg/kg.

The detected concentrations of lead in waterfowl from the Green Bay area are similar to those from reference and background locations. In addition, due to the migratory nature of Canada geese, these concentrations would be nearly impossible to attribute to any one location. Therefore, no further evaluation of lead in waterfowl tissue is warranted for the human health risk assessment.

5.9 Focused Evaluation of Exposures to PCBs from Fish Ingestion

In Section 5.7, cancer risks and noncancer hazard indices were calculated for a variety of receptors. The receptors with the highest cancer risks and hazard indices were recreational anglers and high-intake fish consumers, and almost all the cancer risk and hazard index were due to exposure to PCBs from ingestion of fish. In this section, a focused evaluation of exposure to PCBs via ingestion of fish is performed.

The section begins by reviewing fish tissue data (Section 5.9.1). Next, the equations used to estimate exposure to total PCBs from ingestion of fish and their associated risks are presented (Section 5.9.2). Then, fish intake assumptions for recreational anglers and high-intake fish consumers based on data provided in Section 5.4.3 are reviewed (Section 5.9.3). These assumptions are used to calculate cancer risks and hazard indices for these receptors to illustrate the sensitivity of cancer risks and hazard indices to different assumptions (Section 5.9.4). The exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993) are also presented along with cancer risks and hazard indices associated with these assumptions (Section 5.9.5).

Many of the exposure assumptions used to calculate exposure are derived from probability distributions. These distributions may reflect variability, uncertainty, or both. A probabilistic risk assessment of the assumptions used for the recreational angler and high-intake fish consumer is presented in Appendix B1 and is summarized in Section 5.9.6. This appendix also includes an evaluation of the assumptions used by Exponent (2000) in their risk assessment of angler exposure to PCBs in fish from the Lower Fox River. The Exponent (2000) risk assessment was performed for the Fox River Group. The evaluation of the Exponent (2000) risk assessment is summarized in Section 5.9.7.

Section 5.9.8 presents a qualitative and quantitative discussion of potential exposures of PCBs to young children, a population sensitive to PCB exposure due to possible developmental health effects. Finally, risk-based concentrations in fish are calculated for different cancer risk and hazard index values (Section 5.9.9).

5.9.1 Concentrations of Total PCBs in Fish

The database of fish tissue concentrations (fillet and skin) for total PCBs includes samples from the species listed in Table 5-75. The most widely fished species include walleye, bass (especially white bass), perch, trout, and salmon, although all the species in Table 5-75 may be caught and eaten.

The concentrations of PCBs in fish over time were examined in Section 2. Different species and sample types (whole body and skin-on fillet) were analyzed over the reaches of the Lower Fox River and zones of Green Bay. The fish concentration data were fitted either with a double exponential function, or a single exponential function (whichever fit the data better). Approximately half of the data sets were best fitted by a double exponential function, and half were best fitted by a single exponential function.

In many cases, the concentrations in fish declined with time. In some cases, the concentrations remained essentially constant over time and in a few cases, the concentrations in fish appeared to increase. For the risk analyses conducted, the concentrations of PCBs in fish are assumed to be constant over time. Such an approach is appropriately conservative and protective of human health. While it might be possible to predict future PCB concentrations in fish, there is substantial uncertainty in such projections. First, historical trends may not be accurate predictors of future trends. The fact that some time trends fit a double exponential function where the concentrations declined at a faster rate in the early eighties than in the late nineties suggests that future declines could be at an even slower rate. Second, the historical data is typically available for a period of 15 to 25 years, whereas the exposure periods of interest are 30 to 50 years. Thus, using historical data to predict future concentrations requires the additional assumption that the historical data will accurately reflect future concentrations over future time periods that are two to three times longer than the historical time period. The use of historical data from a 25-year period to predict concentrations over the next 5 years will give far more reliable results than the use of this same historical data to predict concentrations over the next 50 years. Third, there is not sufficient data to evaluate time trends in every species that people typically eat for every reach of the Lower Fox River and every zone of Green Bay.

The remainder of this section discusses concentrations of PCBs in fish using the most recent data (i.e., data from 1989 or 1990 to the present). Table 5-76 presents total PCB concentration data for each reach of the Lower Fox River. The data are summarized for all fish samples and for carp, perch (including white perch and yellow perch), walleye, and white bass. For each group, data are presented for all samples, including all samples collected in the 1990s. The data for the De Pere to Green Bay Reach include fish samples from this reach and from Zone 2 of Green Bay. Since these two areas provide similar habitat and fish can swim freely between them, the fish from the two areas were combined. The data for walleye are from 1989 on for the De Pere to Green Bay Reach. The following statistics are provided: the number of samples, the number of samples where PCBs were detected, the minimum detected concentration, the median or 50^{th} percentile concentration, the average concentration, the 95^{th} percentile concentration, the maximum detected concentration, and the standard deviation. These data indicate that the average concentrations for all fish samples in the 1990s are lower than the average of all fish samples by factors ranging from 1.8 to 4.4 in the various reaches of the Lower Fox River.

For the Appleton to Little Rapids Reach, no carp fillet samples were available from the 1990s data. However, carp whole body samples were available for this reach. As discussed in Section 7, a fillet-to-whole body ratio of 0.53 was developed for carp. This ratio was multiplied by the whole body concentration to estimate a fillet concentration. Table 5-77 presents the number of fillet samples, average fillet concentration, number of whole body samples, and average whole body concentration for each reach of the Lower Fox River and each zone of Green Bay. Table 5-77 also presents the result of using the whole body concentration multiplied by the fillet-to-whole body ratio to estimate the fillet concentration. For the Appleton to Little Rapids Reach, the mean total PCB fillet concentration was estimated to be 1.368 mg/kg. This value was used in the risk calculations for the Appleton to Little Rapids Reach.

Table 5-78 presents total PCB concentration data in Green Bay. As with the Lower Fox River, the data are summarized for all fish samples, and for carp, perch, walleye, and white bass. For each group except all fish samples and walleye, data are presented for all samples, including all samples collected in the 1990s. For walleye, the data from 1989 are included in the data set for the 1990s. The walleye data from 1989 are also included in the all fish sample data set. These data indicate that the average concentrations for all fish samples in the 1990s are lower than the average of all fish samples by factors ranging from 1.6 to 3.4 in the zones of Green Bay.

To provide perspective on the fish concentration data, fish concentrations in Lake Winnebago were examined. Table 5-79 presents the available fillet-on-skin fish data for Lake Winnebago. The average concentration of PCBs in Lake Winnebago fish is 63 μg/kg. For all fish samples in the 1990s in the various reaches of the Lower Fox River, the average concentrations range from 603 μg/kg to 1,344 μg/kg. In Green Bay zones, the average concentrations range from 907 μg/kg to 1,268 μg/kg. These concentrations are nine to 21 times higher than the background concentration of 63 μg/kg.

5.9.2 Equations for Calculating Cancer Risks, Hazard Indices, and Target Concentrations in Fish

This section presents the equations used to calculate cancer risks and hazard indices from ingestion of fish. These are essentially a restatement of the equations presented in Section 5.4.2. Also presented in this section are the equations used to calculate target concentrations in fish tissue (i.e., concentrations in fish associated with a particular cancer risk or hazard index level).

Cancer Risk Evaluation

The equation used to assess cancer risks from ingestion of fish is:

$$R = I \cdot CSFo$$

where:

- R = cancer risk,
- I = intake from ingestion of fish averaged over a lifetime (mg/kg-day), and
- $CSFo$ = oral cancer slope factor [(mg/kg-day)$^{-1}$].

The intake from fish ingestion averaged over a lifetime is given by:

$$I = \frac{Cfish \cdot IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATc}$$

where:

- $Cfish$ = concentration in fish (mg/kg),
- IR = fish ingestion rate (g/day),
- RF = reduction factor due to trimming and cooking fish (mg/mg),
- ABS = absorption factor for ingestion of fish (mg/mg),

CF = 10^{-3} kg/g,
EF = exposure frequency (days/yr),
ED = exposure duration (years),
BW = body weight (kg), and
ATc = averaging time for cancer risks (days).

The intake equation can be rewritten as:

$$I = Cfish \cdot IntFacC$$

$$IntFacC = \frac{IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATc}$$

where:
$IntFacC$ = intake factor for cancer risk [$(mg/kg)^{-1}$]

The equation for assessing cancer risks from ingestion of fish can be rewritten as:

$$R = Cfish \cdot IntFacC \cdot CSFo$$

This equation can be rearranged to give the fish concentration for a particular target risk (*TR*):

$$Cfish = \frac{TR}{IntFacC \cdot CSFo}$$

Noncancer Effects Evaluation

The equation for calculating the chronic hazard index from ingestion of fish is:

$$HI = \frac{I}{RfDo}$$

where:
HI = chronic, noncancer hazard index,
I = intake from ingestion of fish averaged over the exposure period (mg/kg-day), and
$RfDo$ = oral reference dose for chronic, noncancer effects (mg/kg-day).

The intake from fish ingestion averaged over the exposure period is given by:

$$Inc = \frac{Cfish \cdot IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATnc}$$

These variables are the same as before except:

ATnc = averaging time for chronic, noncancer effects (days)

The intake equation can be rewritten:

$$I = Cfish \cdot IntFacNC$$

$$IntFacNC = \frac{IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATnc}$$

where:

IntFacNC = intake factor for chronic, noncancer effects $[(mg/kg)^{-1}]$

The equation for calculating the chronic hazard index from ingestion of fish can be rewritten as:

$$HI = \frac{Cfish \cdot IntFacNC}{RfDo}$$

This equation can be rearranged to give the fish concentration for a particular target hazard index (*THI*):

$$Cfish = \frac{THI \cdot RfDo}{IntFacNC}$$

5.9.3 Intake Assumptions for Recreational Anglers and High-intake Fish Consumers and Toxicological Parameters

This section presents the intake assumptions and toxicological parameters used to solve the previously defined equations for recreational anglers and high-intake fish consumers. Table 5-80 presents the values for the recreational anglers. Intake assumptions for a reasonable maximum exposure (RME) scenario and for a central tendency exposure (CTE) scenario are presented for three studies of fish ingestion: the 1989 and 1993 surveys of Michigan anglers by West *et al.* (1989, 1993) and the 1989 survey of Wisconsin anglers by Fiore *et al.* (1989).

Also included in Table 5-80 are assumptions based on an average of the 1989 and the 1993 survey of Michigan anglers. All parameters in Table 5-80 except *IR* (the average daily fish ingestion rate) are identical for the two studies. Thus, for the case entitled “Average of Michigan Studies,” the *IR* values from the 1989 and

1993 studies were averaged. These average values were used to calculate exposures to the recreational angler in the baseline risk characterization presented in Section 5.7. The rationale for this averaging is discussed in Section 5.4.3.

Table 5-81 provides the values for the high-intake fish consumers. Intake assumptions for an RME scenario and a CTE scenario are presented for three subpopulations: low-income minority high-intake fish consumers using data from West *et al.* (1993); Native American high-intake fish consumers using data from Fiore *et al.* (1989) that were modified as described in Section 5.3; and Hmong high-intake fish consumers using data from Hutchison and Kraft (1994). The data from Hutchison and Kraft (1994) are used for the Hmong rather than the data from Hutchison (1998), because the study by Hutchison and Kraft (1994) examined fishing patterns by Hmong from all locations (i.e., all reaches of the Lower Fox River and Green Bay as well as other locations such as Lake Winnebago) while the study by Hutchison (1998) only considered fishing from the De Pere to Green Bay Reach. Thus, the study by Hutchison and Kraft (1994) provides a more comprehensive picture of the fishing habits of the Hmong and, consequently, is used here.

All the values in Tables 5-80 and 5-81 were discussed in detail in Section 5.4.3, but selected values are reviewed briefly here.

RF = The reduction factor that provides the fraction of total PCBs remaining in the fish after cooking. Based on data reviewed by Anderson *et al*. (1993), a reduction factor of 50 percent was selected, as discussed in Section 5.4.3 under the subsection entitled "Overview of Possible Fish Ingestion Assumptions."

ABS = The absorption factor is assumed to be 1.0 for evaluating both cancer and noncancer effects. The cancer slope factor for PCBs is derived to be used with an absorption factor of 1.0. The *RfD* for Aroclor 1254 is based on a study where adult female rhesus monkeys were exposed to PCBs through ingestion of gelatin capsules, so their absorption is presumed to be similar to the absorption from ingestion of fish, which is believed to be quite high (PCBs in food are absorbed with an efficiency of 75 to 100 percent).

ED = As discussed in Section 5.4.3, this value is set to 50 years for the RME scenario and 30 years for the CTE scenario.

BW = The body weight is taken from EPA's *Exposure Factors Handbook* (EPA, 1997b) and is set to 71.8 kg for both the RME and CTE scenarios.

ATc = The averaging time for calculating the average daily intake over a lifetime was 75 years multiplied by 365 days/yr from EPA's *Exposure Factors Handbook* (EPA, 1997b).

ATnc = The averaging time for calculating the average daily dose over the exposure period is 365 days/yr multiplied by the exposure duration (*ED*).

CSFo = The oral slope factor was set to 2 $(mg/kg\text{-}day)^{-1}$ as specified in EPA (1996d) for evaluating fish ingestion.

RfDo = The oral reference dose for Aroclor 1254 of 2.0×10^{-5} mg/kg-day was used as discussed in Section 5.6.9.

The values for *IR* (fish ingestion rate) and *EF* (exposure frequency) vary for each scenario and each study in Tables 5-80 and 5-81. These values are discussed in detail in Section 5.4.3 under the subsection entitled "Overview of Possible Fish Ingestion Assumptions." This discussion is not repeated here.

5.9.4 Cancer Risks and Hazard Indices for Recreational Anglers and High-intake Fish Consumers

Tables 5-82 and 5-83 present the calculated cancer risks for the recreational angler in each reach of the Lower Fox River and each zone of Green Bay, respectively. Tables 5-84 and 5-85 present the calculated hazard indices for the recreational angler in each reach of the Lower Fox River and each zone of Green Bay. Cancer risks and hazard indices are presented for RME and CTE scenarios for the 1989 Michigan angler study (West *et al.*, 1989), the 1993 Michigan angler study (West *et al.*, 1993), the average of the two Michigan studies, and the 1989 Wisconsin angler study (Fiore *et al.*, 1989). The most recent average fish concentration data in Tables 5-77 and 5-79 were used in this analysis.

Also presented in these tables are the risks calculated for the background concentration of PCBs in fish in Lake Winnebago. The risks associated with background concentrations in fish range from 2.1×10^{-5} to 4.6×10^{-5} for the RME scenario and from 3.9×10^{-6} to 6.0×10^{-6} for the CTE scenario. The hazard indices associated with this background concentration in fish range from 0.8 to 1.7 for the RME scenario and from 0.2 to 0.4 for the CTE scenario.

For the Lower Fox River, the range of risks estimated for the recreational anglers are provided in the following table. Risks are provided for the RME and CTE scenarios and for all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s. It should be noted that the term "Lowest Risk" refers to the lowest risk to recreational anglers in Table 5-82, not the lowest possible risk. The lowest possible risk is 0 (i.e., the risk of eating no fish from the Lower Fox River). Similarly, the term "Highest Risk" refers to the highest risk to recreational anglers in Table 5-82, not the highest possible risk. Thus, the ranges presented in the table below represent the range of values in Table 5-82 and reflect differences in intake assumptions and fish concentrations.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	2.1×10^{-4}	4.5×10^{-4}	9.7×10^{-4}
CTE Scenario	3.8×10^{-5}	6.9×10^{-5}	1.3×10^{-4}
All Carp Samples			
RME Scenario	1.1×10^{-3}	1.4×10^{-3}	2.3×10^{-3}
CTE Scenario	2.0×10^{-4}	2.3×10^{-4}	3.0×10^{-4}
All Perch, Walleye, and White Bass Samples			
RME Scenario	7.0×10^{-5}	3.2×10^{-4}	1.7×10^{-3}
CTE Scenario	1.3×10^{-5}	5.2×10^{-5}	2.2×10^{-4}

Figure 5-12 presents the range of risks to the recreational angler in the Lower Fox River for all fish samples in the 1990s. Also presented in Figure 5-12 are the range of risks for the high-intake fish consumers which will be discussed shortly. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The highest risks are for carp. The highest risk, median risk, and lowest risk for carp are higher than the corresponding risks for all fish samples. The risks for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers, show greater variation. The lowest risk in this group is lower than the lowest risk for all fish samples, but the highest risk for perch, walleye, and white bass samples is higher than the highest risk for all fish samples. The median risk for all perch, walleye, and white bass samples is similar to the median risk for all fish samples.

To illustrate how cancer risks vary by reach, the maximum risks for the recreational angler calculated for all fish samples are presented by river reach in the table below.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	7.0×10^{-4}	6.6×10^{-4}	4.4×10^{-4}	9.7×10^{-4}
CTE	9.1×10^{-5}	8.6×10^{-5}	5.7×10^{-4}	1.3×10^{-4}

Figure 5-13 plots these cancer risks by river reach for the recreational anglers. The maximum cancer risks to high-intake fish consumers are also presented in Figure 5-13. The maximum risks to recreational anglers occur in the De Pere to Green Bay Reach and the minimum risks occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of risks estimated for the recreational anglers are provided in the following table. As before, risks were calculated using concentration data from fish collected in the 1990s plus walleye data from 1989.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	3.2×10^{-4}	5.0×10^{-4}	9.8×10^{-4}
CTE Scenario	5.9×10^{-5}	8.4×10^{-5}	1.3×10^{-4}
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	2.3×10^{-4}	5.2×10^{-4}	1.4×10^{-3}
CTE Scenario	4.2×10^{-5}	7.8×10^{-5}	1.9×10^{-4}

Figure 5-14 presents the range of risks for recreational anglers in Green Bay for all fish samples in the 1990s plus walleye data from 1989. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The median risk for all fish samples is similar to the median risk for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers.

To illustrate how cancer risks vary by zone, the maximum risks calculated for all fish samples are presented by zone in the table below for recreational anglers.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	9.8×10^{-4}	7.5×10^{-4}	6.9×10^{-4}
CTE	1.3×10^{-4}	9.8×10^{-5}	9.0×10^{-5}

Figure 5-15 plots these cancer risks by zone. The maximum cancer risks occur in Zone 3A and the minimum risks occur in Zone 4.

For the Lower Fox River, the range of hazard indices estimated for the recreational anglers are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s.

Fish Samples/Scenario	Lowest HI	Median HI	Highest HI
All Fish Samples			
RME Scenario	7.7	16.8	36.5
CTE Scenario	2.4	4.3	8.0
All Carp Samples			
RME Scenario	40.5	53.9	86.2
CTE Scenario	12.4	14.6	18.8
All Perch, Walleye, and White Bass Samples			
RME Scenario	2.6	12.1	62.3
CTE Scenario	0.8	3.3	13.6

Figure 5-16 presents the range of hazard indices for recreational anglers in the Lower Fox River for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The highest hazard indices are for carp. The median hazard index for all fish samples is similar to the median hazard index for perch, walleye, and white bass.

To illustrate how hazard indices vary by reach, the maximum hazard index calculated for all fish samples are presented by river reach in the table below for recreational anglers.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	26.1	24.7	16.4	36.5
CTE	5.7	5.4	3.6	8.0

Figure 5-17 plots these hazard indices by river reach. The maximum hazard indices occur in the De Pere to Green Bay Reach and the minimum hazard indices occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of hazard indices estimated for the recreational anglers are provided in the following table.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	12.1	18.9	36.9
CTE Scenario	3.7	5.3	8.0
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	8.7	19.4	53.1
CTE Scenario	2.6	4.9	11.6

Figure 5-18 presents the range of hazard indices for recreational anglers in Green Bay for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The median hazard index for all fish samples is similar to the median hazard index for perch, walleye, and white bass.

To illustrate how hazard indices vary by zone, the maximum hazard indices for recreational anglers calculated for all fish samples are presented by zone in the table below.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	36.9	28.2	25.8
CTE	8.0	6.2	5.6

Figure 5-19 plots these hazard indices by zone for the recreational angler. The maximum hazard indices occur in Zone 3A and the minimum hazard indices occur in Zone 4.

Tables 5-86 and 5-87 present the calculated cancer risks for the high-intake fish consumer in each reach of the Lower Fox River and each zone of Green Bay, respectively. Tables 5-88 and 5-89 present the calculated hazard indices for the high-intake fish consumer in each reach of the river and each zone of the bay. Cancer risks and hazard indices are presented for RME and CTE scenarios for a low-income minority angler, based on the data from West *et al.* (1993); a Native American angler using data from Peterson *et al*. (1994) and Fiore *et al*. (1989); and a Hmong angler based on data from Hutchison and Kraft (1994).

Also presented in these tables are the risks calculated for the background concentration of PCBs in fish in Lake Winnebago. The risks associated with this background concentration in fish range from 1.9×10^{-5} to 6.4×10^{-5} for the RME scenario and from 2.6×10^{-6} to 1.5×10^{-5} for the CTE scenario. The hazard indices associated with this background concentration in fish range from 0.7 to 2.4 for the RME scenario and from 0.2 to 0.9 for the CTE scenario.

For the Lower Fox River, the range of risks estimated for the high-intake fish consumers are provided in the following table. Risks are provided for the RME and CTE scenarios and for all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	1.8×10^{-4}	5.5×10^{-4}	1.4×10^{-3}
CTE Scenario	2.5×10^{-5}	9.9×10^{-5}	3.2×10^{-4}
All Carp Samples			
RME Scenario	3.0×10^{-4}	1.1×10^{-3}	3.2×10^{-3}
CTE Scenario	4.2×10^{-5}	2.1×10^{-4}	7.6×10^{-4}
All Perch, Walleye, and White Bass Samples			
RME Scenario	4.6×10^{-5}	3.1×10^{-4}	2.3×10^{-3}
CTE Scenario	6.3×10^{-6}	5.9×10^{-5}	5.5×10^{-4}

Figure 5-12 presents the range of risks in the Lower Fox River for all fish samples in the 1990s for the high-intake fish consumers. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The highest risks are for carp. The median risk for all fish samples is similar to the median risk for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers.

To illustrate how cancer risks vary by reach, the maximum risks for high-intake fish consumers calculated for all fish samples are presented by river reach in the table below.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	9.8×10^{-4}	9.3×10^{-4}	6.2×10^{-4}	1.4×10^{-3}
CTE	2.3×10^{-4}	2.2×10^{-4}	1.4×10^{-4}	3.2×10^{-4}

Figure 5-13 plots these cancer risks by river reach for the high-intake fish consumers. The maximum cancer risks to high-intake fish consumers occur in the De Pere to Green Bay Reach and the minimum risks occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of risks estimated for the high-intake fish consumers are provided in the following table.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	2.9×10^{-4}	7.1×10^{-4}	1.4×10^{-3}
CTE Scenario	4.0×10^{-5}	1.2×10^{-4}	3.3×10^{-4}
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	2.0×10^{-4}	6.4×10^{-4}	2.0×10^{-3}
CTE Scenario	2.8×10^{-5}	1.1×10^{-4}	4.7×10^{-4}

Figure 5-14 presents the range of risks in Green Bay for all fish samples in the 1990s for the high-intake fish consumers. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The median risk for all fish samples is similar to the median risk for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers.

To illustrate how cancer risks vary by zone, the maximum risks for the high-intake fish consumer calculated for all fish samples are presented by zone in the table below.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	1.4×10^{-3}	1.1×10^{-3}	9.7×10^{-4}
CTE	3.3×10^{-4}	2.5×10^{-4}	2.3×10^{-4}

Figure 5-15 plots these cancer risks for the high-intake fish consumer by zone. The maximum cancer risks occur in Zone 3A and the minimum risks occur in Zone 4.

For the Lower Fox River, the range of hazard indices estimated for the high-intake fish consumers are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	6.8	20.8	51.5
CTE Scenario	1.6	6.2	20.1
All Carp Samples			
RME Scenario	11.4	38.6	121.5
CTE Scenario	2.6	12.6	47.5
All Perch, Walleye, and White Bass Samples			
RME Scenario	1.7	11.7	87.9
CTE Scenario	0.4	3.7	34.4

Figure 5-16 presents the range of hazard indices for high-intake fish consumers in the Lower Fox River for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The highest hazard indices are for carp. The median hazard index for all fish samples is similar to the median hazard indices for perch, walleye, and white bass.

To illustrate how hazard indices vary by reach, the maximum hazard index for high-intake fish consumers calculated for all fish samples are presented by river reach in the table below.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	36.8	34.9	23.1	51.5
CTE	14.4	13.6	9.0	20.1

Figure 5-17 plots these hazard indices for high-intake fish consumers by river reach. The maximum hazard indices occur in the De Pere to Green Bay Reach and the minimum hazard indices occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of hazard indices estimated for the high-intake fish consumers are provided in the following table.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	10.7	26.5	52.0
CTE Scenario	2.5	7.3	20.3
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	7.6	24.0	74.9
CTE Scenario	1.8	7.0	29.3

Figure 5-18 presents the range of hazard indices for high-intake fish consumers in Green Bay for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The median hazard index for all fish samples is similar to the median hazard index for perch, walleye, and white bass.

To illustrate how hazard indices vary by zone, the maximum hazard indices for high-intake fish consumers calculated for all fish samples are presented by zone in the table below.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	52.0	39.8	36.4
CTE	20.3	15.6	14.2

Figure 5-19 plots these hazard indices for high-intake fish consumers by zone. The maximum hazard indices occur in Zone 3A and the minimum hazard indices occur in Zone 4.

While difficult to quantify, it should be noted that anglers can potentially be exposed to PCBs via ingestion of fish caught from tributaries to the Lower Fox River or Green Bay to the extent that fish migrate upstream into these tributaries.

5.9.5 Cancer Risks and Hazard Indices Associated with Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

For additional perspective, cancer risks and noncancer hazard indices were also calculated using the exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). The intake assumptions are provided in Table 5-90. These values are provided for four fish consumption scenarios: unlimited consumption, one meal per week, one meal per month, and six meals per year. The parameters in Table 5-90 are the same as those in Tables 5-80 and 5-81 except for *IR*, *EF*, *ED*, and *ATnc*. The fish ingestion rate, *IR*, was set to 227 g/day (about 8 ounces), the same assumption used for the 1989 Wisconsin angler study (Fiore *et al.*, 1989), the Native American high-intake fish consumer (Peterson, *et al.*, 1994; Fiore *et al.*, 1989), and the Hmong/Laotian high-intake fish consumer (Hutchison and Kraft, 1994; Hutchison, 1999). The exposure frequency, *EF*, is set by the exposure scenario (e.g., one meal per week translates into an *EF* of 52 days/yr). The value of *EF* for the unlimited consumption scenario is 225 days/yr. This was calculated by Anderson *et al.* (1993) to be an average daily intake of fish of 140 g/day, which is the 90^{th} percentile of fish consumption rates for recreational anglers reported in the 1989 version of EPA's *Exposure Factors Handbook* (EPA, 1989a). The value of 140 g/day is calculated as:

$$\frac{(227\ g/day \times 225\ days)}{356\ days}$$

Tables 5-91 and 5-92 present the calculated cancer risks for each fish consumption scenario in each reach of the Lower Fox River and each zone of Green Bay, respectively. Tables 5-93 and 5-94 present the calculated hazard indices for each fish consumption scenario in each reach of the Lower Fox River and each zone of Green Bay. The most recent average fish concentration data in Tables 5-77 and 5-78 were used in this analysis. Also presented in these tables are the risks calculated for the background concentration of PCBs in fish in Lake Winnebago.

It should be noted that the cancer risks and hazard indices presented in Tables 5-91 through 5-94 are for generic fish consumption **scenarios** and **do not** represent cancer risks or hazard indices based upon actual fish consumption behavior.

The following table summarizes the estimated cancer risks for the four fish consumption scenarios in each reach of the Lower Fox River using the concentration of PCBs for all fish samples. All risks are greater than the 10^{-6} target. Estimated risks for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum cancer risk for unlimited consumption is greater than the maximum cancer risk for a high-intake fish consumer in the focused evaluation.

Reach	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts	1.9×10^{-3}	4.4×10^{-4}	1.0×10^{-4}	5.1×10^{-5}
Appleton to Little Rapids	1.8×10^{-3}	4.2×10^{-4}	9.7×10^{-5}	4.9×10^{-5}
Little Rapids to De Pere	1.2×10^{-3}	2.8×10^{-4}	6.4×10^{-5}	3.2×10^{-5}
De Pere to Green Bay	2.7×10^{-3}	6.2×10^{-4}	1.4×10^{-4}	7.2×10^{-5}

The following table summarizes the estimated cancer risks for the four fish consumption scenarios in each zone of Green Bay using the concentration of PCBs for all fish samples. As in the previous table, all risks are greater than the 10^{-6} target. Estimated risks for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum cancer risk for unlimited consumption is greater than the maximum cancer risk for a high-intake fish consumer in the focused evaluation.

Zone	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A	2.7×10^{-3}	6.3×10^{-4}	1.4×10^{-4}	7.2×10^{-5}
Green Bay Zone 3B	2.1×10^{-3}	4.8×10^{-4}	1.1×10^{-4}	5.5×10^{-5}
Green Bay Zone 4	1.9×10^{-3}	4.4×10^{-4}	1.0×10^{-4}	5.1×10^{-5}

The following table summarizes the estimated hazard indices for the four fish consumption scenarios in each reach of the Lower Fox River using the concentration of PCBs for all fish samples. All hazard indices are greater than the target of 1.0 with the exception of the six-meals-per-year scenario in the Little Rapids to De Pere Reach. Estimated hazard indices for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum hazard index for unlimited consumption is greater than the maximum hazard index for a high-intake fish consumer in the focused evaluation.

Reach	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts	48.0	11.1	2.6	1.3
Appleton to Little Rapids	45.5	10.5	2.4	1.2
Little Rapids to De Pere	30.1	7.0	1.6	0.8
De Pere to Green Bay	67.2	15.5	3.6	1.8

The following table summarizes the estimated hazard indices for the four fish consumption scenarios in each zone of Green Bay using the concentration of PCBs for all fish samples. All hazard indices are greater than the target of 1.0. Estimated hazard indices for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum hazard index for unlimited consumption is greater than the maximum hazard index for a high-intake fish consumer in the focused evaluation.

Zone	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A	67.8	15.7	3.6	1.8
Green Bay Zone 3B	51.9	12.0	2.8	1.4
Green Bay Zone 4	47.5	11.0	2.5	1.3

5.9.6 Summary of Probabilistic Risk Assessment

Appendix B1 expands upon the focused evaluation of exposure to PCBs in fish provided in this section, by providing a probabilistic assessment of risks and hazard indices for receptors potentially exposed to PCBs present in fish in the Lower Fox River and Green Bay. The probabilistic risk evaluation presented in Appendix B1 was performed in accordance with draft EPA guidance (EPA, 1999), and accounts for variability, as well as uncertainty in some of the intake assumptions. In this context, variability represents the true diversity or heterogeneity in a variable. For example, body weight varies throughout the population. The more that body weight is studied, the better the variation is characterized, but no amount of study will eliminate the variation in body weight. Uncertainty represents a lack of knowledge about a particular variable. The more that a particular variable is studied, the more the uncertainty is reduced.

The probabilistic risk assessment is intended to support and complement the point estimates of risks and hazard indices. The probabilistic risk assessment is not intended to be the principal basis for decisions regarding the need for remedial action at a site. EPA guidance specifies that point estimates of risks and hazard indices calculated using point estimates of intake parameters for RME and CTE scenarios are the principal basis for such decisions. Therefore, the probabilistic risk assessment presented in Appendix B1 does not supercede the point estimate evaluation presented in Section 5.9.4, but is intended to supplement and complement the point estimates of risks and hazard indices.

In Appendix B1, a probabilistic evaluation of risks and hazard indices was performed. In this analysis, the influence of variability was examined by developing probability distributions for the following exposure parameters: fish concentration, fish ingestion rate, exposure frequency, reduction factor, exposure duration, and body weight. For the concentration of PCBs in fish, the following distributions were used:

- Concentration distribution developed by Exponent (2000) in their probabilistic risk assessment for the entire Lower Fox River,

- Concentration distribution developed from data for all fish species in the Little Lake Butte des Morts Reach, and

- Concentration distribution developed from data for all fish species in the De Pere to Green Bay Reach.

For fish ingestion rate and exposure frequency, distributions were developed for the following categories of anglers:

- Recreational anglers, and
- High-intake fish consumers.

For reduction factor, exposure duration, and body weight, distributions were developed and applied to all receptors. For each category of angler, probability distributions were developed for fish ingestion rate and exposure frequency using different studies as the basis for the distributions. For example, for the recreational anglers, studies by West *et al*. (1989, 1993), Fiore *et al*. (1989), and Exponent (2000) were used to develop four sets of probability distributions for fish ingestion rate and exposure frequency. These different sets of distributions provide a measure of the uncertainty in estimating the distribution of fish ingestion rate and exposure frequency for recreational anglers. Similarly, for the high-intake fish consumer, a study by West *et al.* (1993) for low-income minority anglers and studies by Hutchison and Kraft (1994) and Hutchison (1999) for Hmong and Laotians were used to develop three sets of probability distributions for fish ingestion rate and exposure frequency. Once again, these different sets of distributions provide a measure of the uncertainty in estimating the distribution of fish ingestion rate and exposure frequency for high-intake fish consumers. The procedures used were consistent with EPA guidance on probabilistic risk assessment (EPA, 1999).

The main results of the probabilistic risk assessment for the Little Lake Butte des Morts and De Pere to Green Bay reaches are summarized in Tables 5-95 through 5-98. These tables provide summary statistics for the calculated risks and hazard indices, including percentile values, and the mean and standard deviation of each distribution. As a point of reference, the CTE and RME values calculated in Section 5.9.4 are also reported in the tables. Figures 5-20 through 5-23 provide a visual comparison of the CTE and RME values with selected values of the risk and hazard index distributions.

These tables and figures show the following.

- The deterministic CTE estimates of risk and hazard index provided in Section 5.9.4 are generally close to the means of the respective probability distributions of risk and hazard index. This is consistent with the interpretation of the CTE as the average risk or hazard index for the exposed population.

- The deterministic RME estimates of risk and hazard index provided in Section 5.9.4 are generally within the 90th to 95th percentiles of the respective probability distributions of risk and hazard index. This is consistent with the interpretation provided in EPA (1999) of the RME as a plausible high-end risk or hazard index for the exposed population.

Consistent with EPA (1999), the results of the four studies of recreational angler fish intakes were combined to evaluate the uncertainty associated with the determination of probability distributions of risks and hazard indices for recreational anglers. Similarly, the three studies of high-intake fish consumers were also combined. The results of the uncertainty analysis for the Little Lake Butte des Morts and De Pere to Green Bay reaches are summarized in Tables 5-99 and 5-100 and on Figures 5-24 through 5-31.

In Tables 5-99 and 5-100 and on Figures 5-24 through 5-31, the ranges of risk or hazard index for a particular percentile of the distribution and mean of the distribution are presented. This range is reflective of the uncertainty associated with the estimate of risk or hazard index at each percentile and at the mean. The data presented in these tables and figures show that the uncertainty in the estimate of the probability distributions of risk and hazard index is moderate, as reflected by the fact that the maximum and minimum values for the ranges are generally within a factor of 10 of each other.

5.9.7 Evaluation of Exponent Risk Assessment

In addition to a probabilistic risk assessment, Appendix B1 presents the assumptions used in the probabilistic risk assessment prepared by Exponent (2000) on behalf of the Fox River Group and compares the results generated for the Exponent (2000) assumptions with the results of the deterministic risk assessment presented in Sections 5.9.2, 5.9.3, and 5.9.4. Risks and hazard indices were calculated in Section 5.9.4 for an RME scenario and a CTE scenario for the four reaches of the Lower Fox River and three zones within Green Bay. Different values of risk and hazard indices were calculated based on different assumptions regarding intake parameters, primarily fish ingestion rate, exposure frequency, exposure duration, and concentrations of PCBs in fish. Exponent (2000) used a probabilistic approach to calculate probability distributions of risks and hazard indices over the whole Lower Fox River, independent of the reach.

The two risk assessments provide different outputs (point value estimates of risks and hazard indices for RME and CTE scenarios in Section 5.9.4, and probability distributions of risk and hazard indices for Exponent [2000]). As such, the results of the two risk assessments are not directly comparable. To better understand the fundamental similarities and differences between the two approaches, RME and CTE values were developed from the Exponent (2000) distributions for each intake parameter and unit risks and unit hazard indices were calculated for the RME and CTE scenarios. Unit risks and unit hazard indices are the risks and hazard indices associated with a concentration of 1 mg/kg PCBs in fish. By calculating unit risks and unit hazard indices, the influence of different fish concentrations in Exponent (2000) as compared to Section 5.9.4 is removed.

The comparison with Exponent assumptions indicated that the intake assumptions used by Exponent (2000) result in generally lower unit risks and hazard indices than the assumptions presented in Section 5.9.3 for recreational anglers. The differences between the unit risks and hazard indices calculated using Exponent (2000) assumptions and the assumptions presented in Section 5.9.3 for recreational anglers depend on the study used in Section 5.9.3 to estimate fish intake assumptions. This difference is generally greatest for the survey of Michigan anglers by West *et al.* (1993), and least for the survey of Wisconsin anglers by Fiore *et al*. (1989).

It should be noted that high-intake fish consumers were evaluated in Sections 5.9.3 and 5.9.4, where high-intake fish consumers are a subset of the recreational angler population who are more highly exposed than the general population of recreational anglers. Three populations of high-intake fish consumers were identified in these sections: low-income minorities, Native Americans, and Hmong/Laotians. Exponent (2000) argued that these populations did not eat significantly more fish from the Lower Fox River and Green Bay, so Exponent (2000) did not evaluate exposures and health effects for these specific populations. Since Exponent (2000) did not explicitly evaluate exposures to high-intake fish consumers, a comparison could not be performed.

5.9.8 Evaluation of PCB Exposures to Young Children

This section presents qualitative and quantitative evaluations of PCB exposure to young children. Three evaluations are presented. In the first evaluation, the potential for long-term developmental effects from short-term (even one-time) exposure is reviewed qualitatively. In the second evaluation, the potential for elevated exposures to PCBs as a result of the transfer of PCBs from a mother to her fetus and infant child is also reviewed qualitatively. In the third evaluation, doses and hazard quotients are calculated for a young child, aged 1 to 7 years, as a result of fish ingestion.

Potential Long-term Developmental Effects from Short-term Exposures

This section discusses the evidence that short-term exposures to high doses of PCBs (even one-time exposures) can result in long-term developmental effects to young children. The discussion is qualitative because there is insufficient toxicological data to make quantitative estimates of potential health effects. This section focuses on exposures to individuals in Taiwan and Japan as a result of PCB contamination of rice oil or cooking oil. These exposures resulted in an outbreak of illness (referred to as Yu-Cheng and Yusho disease, respectively) which included chloracne, hyperpigmentation, and Meibomian gland dilation (Rogan *et al.*, 1988).

These exposures also resulted in significant health effects to infants born to mothers in both Taiwan and Japan. While the effects were similar to those discussed in the next subsection, the source of PCB exposure (rice or cooking oil ingestion) is different from the source of the exposures described in the next subsection (fish ingestion). Also, the ingestion of the contaminated rice and cooking oil is believed to have resulted in much higher short-term exposures than the ingestion of contaminated fish described in the next subsection.

Even several years after the incident, women who were exposed to the contaminated oil gave birth to infants with abnormalities. The exposed children were small for gestational age and had abnormalities of the lungs, skin, and teeth. In addition, these children exhibited a delay in mental and psychomotor development. Follow-up studies of the Taiwan case have shown that neurobehavioral deficits and developmental delays may persist in older children (Chen *et al.*, 1992; Guo *et al.*, 1995; Chao *et al.*, 1997). However, it should be noted that these results may have been associated with the presence of dibenzofurans which were also present in the contaminated oil.

Effects on the immune system were also studied in the Yu-Cheng and Yusho populations (Tryphonas, 1995). Adverse effects included persistent respiratory distress (in half of Yu-Cheng persons studied); decreases in antibody levels 2 years after exposure (normal at 3 years); decrease in percentage of T-lymphocytes (Yu-Cheng) and increase in T-helper cells and decrease in T-suppressor cells (Yusho) 14 years after exposure; and enhanced responses to mitogens (Guo *et al.*, 1995).

Exposure to the Fetus and Infant from the Mother

This section discusses potential exposures to fetuses and infants from mothers who consumed PCB-contaminated fish. For the fetal stage, exposure occurs via transfer from the mother to the fetus across the placenta. For the infant stage, exposure occurs via transfer from the mother to the infant through breast milk. Transfer of maternal PCBs across the placenta and into breast milk can clearly result in significant exposures *in utero* and to a nursing infant (Dekoning and Karmaus, 2000). Exposure to PCBs in breast milk is estimated to be a major contributor to a child's body burden at 42 months of age (Lanting *et al.*, 1998) and to account for over 10 percent of an individuals cumulative PCB intake through 25 years of age (Patandin *et al.*, 1999).

In Section 5.6.2, a number of studies were reviewed that present evidence that such exposures result in a variety of developmental, neurological, and immune system effects. From a developmental perspective, Fein *et al.* (1984a, 1984b) studied the effects of low-level chronic exposure to PCBs in pregnant women and their newborn offspring from consumption of Lake Michigan fish and reported that low levels of PCBs caused decreases in birth weight, head circumference, and gestational age of the newborn.

From a neurological perspective, Fein *et al.* (1984a, 1984b) also reported immaturity of reflexes and depressed responsiveness in infants exposed to PCBs. Newborns of high-fish-consuming mothers exhibited a greater number of abnormal reflexes, less mature autonomic responses, and less attention to visual/auditory stimuli in comparison to newborns of no- or low-fish-consuming mothers (Lonky *et al.*, 1996). PCBs, dioxins, and furans present in breast milk were associated with reduced neonatal neurologic optimality in breast-fed infants 2 to 3 weeks old (Huisman *et al.*, 1995a, 1995b).

From an immune system perspective, Smith (1984) and Humphrey (1988) found that maternal serum PCB levels during pregnancy (of women who consumed PCB-contaminated Great Lakes/St. Lawrence fish) were positively associated with the number and type of infectious illnesses which occurred in infants. In infants exposed to PCBs and dioxins pre- and postnatally, Weisglas-Kuperus *et al.* (1995) found lower monocyte and granulocyte counts for 3-month-old infants, and increased total T-cell counts and cytotoxic T-cell counts for children 18 months old. Weisglas-Kuperus *et al.* (2000) also found the effects of prenatal exposure to

PCBs and dioxins persisted into childhood and might be associated with a greater susceptibility to infectious diseases.

Unfortunately, methods to model exposures due to placental transfer or breast-feeding are not well established. PCB exposures *in utero* are based on the mother's current and past history of PCB exposures. PCB exposures in breast milk depend not only on maternal PCB exposure levels, but can also be significantly influenced by factors such as maternal age, number of children, length of time between children, and duration of breast-feeding (Vartiainen *et al.*, 1998; Rogan *et al.*, 1986). A mother's body burden of PCBs has been estimated to decrease 20 percent for every 3 to 6 months of breast-feeding (Patandin *et al.*, 1999; Rogan and Gladen, 1985), after which PCB body burdens are gradually restored. Well-established methodologies for evaluating PCB exposures in pregnant women and nursing children are not available at this point. Therefore, it is also not possible (through available data or modeling) to make a relevant, direct comparison between exposure levels estimated for anglers in this risk assessment (reported in mg/kg-day) and exposure levels for pregnant women and nursing children reported in human studies (typically reported as PCB concentrations in blood or breast milk), without introducing a considerable level of uncertainty.

However, since a variety of developmental effects (Fein *et al.,* 1984a, 1984b), neurological effects (Fein *et al.,* 1984a, 1984b; Lonky *et al.,* 1996; Huisman *et al.,* 1995a, 1995b), and immune system effects (Smith, 1984; Humphrey, 1988; Weisglas-Kuperus *et al.,* 1995, 2000) have been observed in infants and children whose mothers consumed fish known to be contaminated with PCBs, it seems plausible that PCB exposures for at least some women consuming fish from the Lower Fox River and Green Bay could be in the same range of PCB exposure levels at which these effects have been observed.

Exposure to a Young Child from Fish Ingestion

This section provides a quantitative evaluation of potential exposure to a young child (age 1 through 7 years) as a result of eating fish. Chronic hazard indices are calculated for a recreational angler child and a high-intake fish consumer child. Calculations are performed for the Little Lake Butte des Morts and the De Pere to Green Bay reaches. The results are compared to results for the adult receptors in these reaches. A 7-year exposure period was chosen because this is the shortest period which is still considered chronic exposure (EPA, 1989c). Cancer risks were not calculated, because cancer risks depend on the cumulative dose over a lifetime. Thus, cancer risks for a young child based on 7 years of exposure are expected to be less than cancer risks for an adult over 30 years (CTE scenario) or 50 years (RME scenario) of exposure. The Little Lake Butte des Morts and De Pere to Green Bay reaches were selected because these two reaches have the highest population density of all river reaches and bay zones and are expected to have the most fishing activity.

As presented previously in Section 5.9.2, the equation for calculating the chronic hazard index from ingestion of fish is:

$$HI = \frac{Inc}{RfDo}$$

where:

- HI = chronic, noncancer hazard index,
- Inc = intake from ingestion of fish averaged over the exposure period (mg/kg-day), and
- $RfDo$ = oral reference dose for chronic, noncancer effects (mg/kg-day).

The chronic oral reference dose (*RfDo*) used in this assessment for PCBs is 2.0×10^{-5} mg/kg-day. The intake from fish ingestion averaged over the exposure period is calculated for the young child using the same equation presented for adults (refer to Section 5.9.2):

$$Inc = \frac{Cfish \cdot IR_C \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED_C}{BW_C \cdot ATnc_C}$$

These intake parameters are the same for the child receptor as those used for the adult receptor with the exception of the fish ingestion rate for the child (IR_C), the exposure duration (ED_C), body weight (BW_C), and non-carcinogenic averaging time ($ATnc_C$).

The fish ingestion rate for the child (IR_C) is calculated using a child-to-adult fish ingestion ratio. Limited data are available on fish ingestion rates for young children. However, these data may be compared to ingestion rates for older children and adults that were measured from the same study. By comparing the ingestion rates between children and adults (from the same study), a ratio may be calculated. This ratio can then be applied to the adult fish ingestion rates selected for use in the focused risk assessment presented in Section 5.9.3.

Two studies providing information on both adult and child fish ingestion rates were found to be appropriate for determining a child-to-adult fish ingestion ratio. The first study, conducted by the EPA (1996f), compiled survey data collected by the U.S. Department of Agriculture (USDA) on intake rates for major food groups. The second study was the West *et al.* (1989) study of Michigan anglers, described previously in this report. Table 5-101 provides the fish ingestion rates for young children in various age groups and the fish ingestion rates for older children and adults from the two studies identified above. The child ingestion rate (measured in grams of fish per day) was divided by the adult ingestion rate (from the same study) to determine a child-to-adult fish ingestion ratio ($Ratio_{CAFI}$). Table 5-101 demonstrates that the ratios range from 0.35 to 0.83, with an average ratio of 0.60. Although the calculated ratios are for children ranging in ages from 1 to 14 years, the calculated average ratio was used to represent children from age 1 through 7 years.

The average child-to-adult fish ingestion ratio was then applied to the adult fish ingestion rate (IR_A) to determine the child fish ingestion rate for each study examined in the focused risk assessment:

$$IR_C = IR_A \cdot Ratio_{CAFI}$$

The exposure duration (ED_C) for a child from ages 1 through 7 is 7 years; this value is used for both the RME and CTE scenarios. The average body weight for a child of this age group (BW_C) is 17.8 kg. This value was calculated using the average of the mean body weights of boys and girls ages 1 through 7 years, as presented in the draft *Child-Specific Exposure Factors Handbook* (EPA, 2000c). The non-carcinogenic averaging time ($ATnc_C$) is equivalent to 365 days/yr multiplied by the exposure duration. Since the ED_C for the young child is determined to be 7 years, the resulting $ATnc_C$ is 2,555 days.

The above factors are presented in Tables 5-102 and 5-103 for the recreational angler child and the high-intake fish consumer child, respectively. Intake assumptions for the recreational angler child are presented for the same fish ingestion studies as those used for the adults: the 1989 survey of Michigan anglers by West *et al.* (1989), the 1993 survey of Michigan anglers by West *et al.* (1993), the average of the two Michigan studies, and the 1989 survey of Wisconsin anglers by Fiore *et al.* (1989). Similarly, intake assumptions for the high-intake fish consumer child are presented for the same fish ingestion studies as those used for adults: West *et al.* (1993) for low-income minorities, Peterson *et al*. (1994) and Fiore *et al*. (1989) for Native Americans, Hutchison and Kraft (1994) for Hmong, and Hutchison (1999) for Hmong and Laotians.

Table 5-104 presents the calculated hazard indices for the recreational angler child in the Little Lake Butte des Morts and De Pere to Green Bay reaches. Hazard indices are presented for RME and CTE scenarios for each of the four angler studies. The most recent average fish concentration data in Table 5-76 were used in this analysis. Also presented in this table are the hazard indices calculated for the background concentration of PCBs in fish in Lake Winnebago.

For the two reaches, the range of hazard indices estimated for the recreational angler children are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and for all fish sampled in the 1990s. The first number in each cell within the table is the hazard index for the young child, while the number after the "/" symbol is the hazard index for the adult from the results presented in Table 5-84. The ranges presented in the table below represent the range of values in Tables 5-84 and 5-104 and reflect differences in intake assumptions and fish concentrations. The calculated hazard indices are about 2.4 times greater for the child than for the adult.

Fish Samples/Scenario	Lowest HI Child/Adult	Median HI Child/Adult	Highest HI Child/Adult
All Fish Samples			
RME Scenario	29.7/12.3	45.8/19	88.4/36.5
CTE Scenario	9.1/3.7	13.1/5.4	19.3/8

Table 5-105 presents the calculated hazard indices for the high-intake fish consumer child in the Little Lake Butte des Morts and De Pere to Green Bay reaches. Hazard indices are presented for RME and CTE scenarios for each of the four angler studies. The most recent average fish concentration data in Table 5-76 were used in this analysis. Also presented in this table are the hazard indices calculated for the background concentration of PCBs in fish in Lake Winnebago.

For the two reaches, the range of hazard indices estimated for the high-intake fish consumer children are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and for all fish samples in the 1990s. The first number in each cell within the table is the hazard index for the young child, while the number after the "/" symbol is the hazard index for the adult from the results presented in Table 5-88. The ranges presented in the table below represent the range of values in Tables 5-88 and 5-105 and reflect differences in intake assumptions and fish concentrations. The calculated hazard indices are about 2.4 times greater for the child than for the adult.

Fish Samples/Scenario	Lowest HI Child/Adult	Median HI Child/Adult	Highest HI Child/Adult
All Fish Samples			
RME Scenario	26.2/10.8	64.1/26.5	124.6/51.5
CTE Scenario	6.0/2.5	18.1/7.5	48.7/20.1

5.9.9 Risk-based Concentrations in Fish

As discussed in Section 5.9.2, the equations for calculating cancer risk from ingestion of fish can be rearranged to calculate a concentration of total PCBs in fish for a specified risk level. Similarly, the equation for calculating hazard index from ingestion of fish can be rearranged to calculate a concentration of total PCBs in fish for a specified hazard index level. Table 5-106 presents risk-based concentrations of total PCBs in fish for recreational anglers for risk levels of 10^{-6}, 10^{-5}, 10^{-4}, and for an HI of 1.0. Figure 5-32 plots these risk-based fish concentrations for each set of intake assumptions and exposure scenarios; and for risks levels of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0. Table 5-107 presents risk-based concentrations of total PCBs in fish for high-intake fish consumers for risk levels of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0. Figure 5-33 plots these risk-based fish concentrations for each set of intake assumptions and exposure scenario; and for risk levels of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0.

The risk-based fish concentrations for the recreational angler cover a range of about three orders of magnitude (1.4×10^{-3} mg/kg to 1.6 mg/kg). For a given set of assumptions, the risk-based fish concentration for an HI of 1.0 always falls between the risk-based fish concentrations for the 10^{-5} and 10^{-4} cancer risk level. The table below presents the risk-based fish concentrations for recreational anglers averaged over the West *et al*. (1989, 1993) and Fiore *et al*. (1989) studies.

Risk or Hazard Index Level	RME (mg/kg)	CTE (mg/kg)
Target Risk = 10^{-6}	0.0024	0.014
Target Risk = 10^{-5}	0.024	0.14
Target Risk = 10^{-4}	0.24	1.4
Target HI = 1.0	0.063	0.22

The risk-based fish concentrations for the high-intake fish consumer cover a range of about three orders of magnitude (9.8×10^{-4} mg/kg to 2.4 mg/kg) and the risk-based fish concentration for a target hazard index of 1.0 always falls in between the risk-based fish concentrations for risk levels of 10^{-5} and 10^{-4}. The table below presents the results of averaging the risk-based fish concentrations using the intake assumptions for the low-income minority, Native American, and Hmong/Laotian anglers. The values based on the study by Hutchison and Kraft (1994) were used in the averages.

Risk or Hazard Index Level	RME (mg/kg)	CTE (mg/kg)
Target Risk = 10^{-6}	0.0014	0.0078
Target Risk = 10^{-5}	0.014	0.078
Target Risk = 10^{-4}	0.14	0.78
Target HI = 1.0	0.038	0.12

Risk-based fish concentrations were also calculated using the exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). These risk-based concentrations are provided in Table 5-108 for cancer risks of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0. These concentrations are plotted on Figure 5-34. These concentrations range from 5.0×10^{-4} mg/kg to 1.9 mg/kg, spanning more than three orders of magnitude depending on the selected cancer risk level and exposure scenario. The risk-based concentration for an HI of 1.0 is between the risk-based concentrations for cancer risks of 10^{-5} and 10^{-4}.

In Table 5-108, the RfD of 2.0×10^{-5} mg/kg-day for Aroclor 1254 was used, which yields a risk-based fish concentration of 0.02 mg/kg for unlimited consumption. When Anderson *et al.* (1993) derived their risk-based fish concentrations, they used an RfD of 5.0×10^{-5} mg/kg-day based on a weight-of-evidence approach that considered epidemiological and animal studies. The risk-based fish concentration that Anderson *et al*. (1993) derived was 0.05 mg/kg for unlimited consumption.

It is interesting to note that the average of the RME risk-based fish concentrations for an HI of 1.0 for the recreational angler (0.063 mg/kg) and high-intake fish consumer (0.038 mg/kg) is also 0.05 mg/kg. The average value of 0.038 mg/kg for the high-intake fish consumer does not include the risk-based fish concentration for Hutchison (1999) since this study underestimates potential fish consumption in the Lower Fox River. The value of 0.05 mg/kg from Anderson *et al.* (1993) falls between the average RME and CTE risk-based concentrations at a 10^{-5} risk level for the recreational angler (0.024 mg/kg to 0.14 mg/kg) and the high-intake fish consumer (0.014 mg/kg to 0.078 mg/kg). The range of values for the high-intake fish consumer does not include the risk-based fish concentration based on the Hutchison (1999) study.

5.10 Uncertainty Analysis

The uncertainties in the human health risk assessment reflect the uncertainties in the two principal components of the risk assessment: the exposure assessment and toxicity assessment. The exposure assessment includes the identification of COPCs, the identification and screening of receptors, the development of intake assumptions, and the calculation of exposure point concentrations. The COPCs were determined based on a screening level risk assessment for the Lower Fox River and Green Bay. Thus, of the various chemicals analyzed in media from the river and bay, the COPCs represent the chemicals which will cause the most significant health effects. Therefore, the baseline human health risk assessment is unlikely to underestimate cancer risks or noncancer health effects because of influences from chemicals that were screened out.

The receptors potentially most exposed were retained for quantitative analysis and reasonable maximum exposures (RMEs) were estimated for each receptor. For selected receptors, exposure assumptions reflecting more typical exposures or central tendency exposures (CTEs) were also developed so that a range of exposures and associated health effects could be determined.

In particular, RME and CTE assumptions were developed for recreational anglers, high-intake fish consumers, and hunters. For recreational anglers and high-intake fish consumers, the critical exposure pathway is ingestion of fish. For recreational anglers, a variety of fish ingestion surveys were evaluated, including the 1989 and 1993 Michigan angler studies of West *et al.* (1989, 1993) and the 1989 Wisconsin angler study of Fiore *et al.* (1989). The data from the two studies by West *et al.* (1989, 1993) are considered the most representative, so these studies were used to estimate fish ingestion rates for the recreational angler. Thus, both RME and CTE fish ingestion assumptions are based on recent surveys of anglers that have undergone peer review.

For the high-intake fish consumers, three subpopulations were examined: low-income minority anglers, Native American anglers, and Hmong/Laotian anglers. For the low-income minority anglers, the data from West *et al.* (1993) was used. For the Native American subpopulation, the data from Peterson *et al.* (1994) was used to adjust data from Fiore *et al.* (1989) to develop fish intake assumptions. For the Hmong/Laotian anglers, data from Hutchison and Kraft (1994), Hutchison (1994), and Hutchison (1999) were used to develop fish intake assumptions. Of the various studies, those of Hutchison and Kraft (1994) and Hutchison (1994) for the Hmong are most specific to the Lower Fox River and Green Bay. Therefore, this study was used for the high-intake fish consumer. The study of Hutchison (1999) monitored actual fishing behavior of Hmong/Laotian anglers in the De Pere to Green Bay Reach, but this study indicated that this behavior was influenced by the existing fish advisories on the river. Therefore, the Hutchison and Kraft (1994) study was used since this study monitored angling behavior from any water body, not just the Lower Fox River and Green Bay. The influence of alternative assumptions for the recreational angler and high-intake fish consumer were investigated in the focused evaluation of fish ingestion.

For calculating exposures to anglers, the concentrations of PCBs in fish were assumed to remain constant. In the focused risk assessment, the most recent fish concentration data (i.e., the fish concentration data from 1990 through 1998) were used to calculate this constant concentration. Over a very long period of time (e.g., 50 to 100 years or more), PCB concentrations in fish are expected to decline. In the shorter term, it is not clear whether or not significant concentration declines will be observed. In the time trends analysis, concentrations of PCBs in fish declined in some cases, remained constant in other cases, and even appeared to increase in a few cases. Given this uncertainty in the time trend of the fish concentration data, it was assumed that the concentrations remained constant, which is a conservative and health protective assumption. It should be noted that the influence of declines in PCB concentrations in fish over time is assessed as part of the alternative-specific risk assessment in the Feasibility Study.

The focus of the exposure and risk assessment of anglers was on adult exposures via fish consumption. The inclusion of a fish ingestion scenario for young children increased the PCB dose per body weight by a factor that is between two and three times greater than the PCB dose per body weight for adults. In addition, the possibility of prior maternal PCB exposures via fish consumption leading to fetal and nursing infant exposures also adds to the uncertainty regarding resultant exposures and risks. These maternal exposures to PCBs in fish can lead to underestimations of exposure and risk.

For hunters, the critical exposure pathway is ingestion of hunted waterfowl. The waterfowl intake assumptions were based on information on the amount of hunted waterfowl that is consumed by hunters that was collected by Amundson (1984). Thus, the intake assumptions for this critical pathway were based on empirical data.

For other exposure pathways for the recreational angler, high-intake fish consumer, and hunter, and for the exposure pathways for all other receptors, conservative default assumptions from the EPA's *Exposure Factors Handbook* (1997b) or conservative assumptions based on professional judgment were used. Therefore, the exposures calculated for these pathways are unlikely to underestimate actual exposures.

For all receptors, exposure point concentrations were estimated in accordance with EPA guidance, which is designed to be conservative. Consequently, the intakes estimated in the exposure assessment are unlikely to underestimate most actual intakes.

As for the toxicity assessment, two types of health effects were evaluated: cancer risks and non-carcinogenic effects. To determine cancer risks, cancer slope factors were found for potentially carcinogenic compounds. However, cancer slope factors are not based upon animal studies where exposure occurs during fetal and infant development. Organisms are particularly sensitive to adverse chemical effects during early life stages. Cancer extrapolation techniques, which use the upper confidence limits of the slope of the dose-response curve, may provide sufficient protection even if early life exposures are not included. To determine non-carcinogenic effects, reference doses were obtained. As with cancer slope factors, reference doses are developed with the intent of not underestimating noncancer effects. While there tends to be conservatism in cancer slope factors and reference doses, there are factors that might increase cancer risks and noncancer hazard indices beyond those derived in this assessment. For instance, the distribution of PCB congeners that bioaccumulate in fish and wildlife do not resemble the distribution of PCB congeners in Aroclors which have been tested in toxicological studies (Cogliano, 1998). Overall, these bioaccumulated PCB congeners are more persistent than PCB congeners found in Aroclors, and the bioaccumulated PCB congeners may also be more toxic than the PCB congeners found in Aroclors tested in toxicological studies (Cogliano, 1998). The distribution of PCB congeners that bioaccumulate in humans is also different than the distribution of PCB congeners in Aroclor mixtures, and these bioaccumulated PCB congeners are also more persistent. It is therefore possible that the distribution of PCB congeners that bioaccumulate in humans are more toxic than the distributions of PCB congeners found in the Aroclors used in toxicological studies (Cogliano, 1998). A final factor which has not been accounted for in the risk assessment is possible synergistic effects from chemical mixtures.

Additionally, two reference doses have been developed for PCBs, one for Aroclor 1016, the other for Aroclor 1254. The reference dose for Aroclor 1016 has undergone external peer review, while the reference dose for Aroclor 1254 has undergone internal peer review within EPA. The reference dose for Aroclor 1254, which is 3.5 times lower than the value for Aroclor 1016, was used in this assessment to evaluate the noncancer effects of exposure to total PCBs. Since the reference dose for Aroclor 1254 is lower than that for Aroclor 1016, this is conservative. In addition, since higher molecular weight PCB congeners tend to preferentially bioaccumulate in fish and since Aroclor 1254 contains more high molecular weight PCB congeners than Aroclor 1016, the use of the reference dose for Aroclor 1254 is appropriate.

Uncertainties associated with the risk characterization portion of the risk assessment for the Lower Fox River and Green Bay result from the uncertainties associated with the exposure and toxicity assessment. The key uncertainties include concentrations of PCBs in sediment and fish over time, the mixture of fish species consumed by individual anglers, the amount of fish caught and eaten from the Lower Fox River and Green Bay over a lifetime, fetal and infant exposures to PCBs, and toxicological criteria based on Aroclor mixtures rather than individual congeners. The exposure assumptions chosen for anglers appear to be balanced, being appropriately protective, but not overly conservative. Further support for this conclusion is found in the quantitative probabilistic analysis presented in Section 5.9. This analysis evaluated the influence of exposure assumptions for anglers and demonstrated that estimates of cancer risks and hazard indices, based on CTE and RME intake assumptions, fell within the desired range of risks and hazard indices on the distributions of risk and hazard index calculated in the probabilistic assessment.

5.11 Summary and Conclusions

5.11.1 Summary

This section presents the baseline human health risk assessment for the Lower Fox River and Green Bay system. The baseline human health risk assessment included the following:

- Identified chemicals of potential concern (COPCs) and performed additional evaluations of PAHs and lead;

- Provided an exposure assessment that identified receptors and exposure pathways, developed intake assumptions for receptors, and determined exposure point concentrations;

- Presented a dose-response assessment for COPCs that reviewed the toxicological characteristics of each COPC and identified cancer slope factors and reference doses;

- Provided a baseline risk characterization where cancer risks and noncancer hazard indices were calculated for each identified receptor population;

- Presented a focused analysis of exposure to PCBs through ingestion of fish for the two receptors with the highest cancer risks and hazard indices: recreational anglers and high-intake fish consumers; and

- Provided a qualitative uncertainty analysis.

The results for the baseline risk characterization and focused risk characterization are summarized below.

Baseline Risk Characterization

In the baseline risk characterization, cancer risks and noncancer hazard indices were calculated for the following receptors:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

To evaluate exposures to these receptors, intake equations were presented and intake assumptions were developed for each receptor. For all receptors, reasonable maximum exposure (RME) assumptions were developed. For the recreational angler, high-intake fish consumer, and hunter (the receptors with the highest exposures), central tendency exposure (CTE) assumptions were also developed. The calculated intakes were combined with the dose-response information to calculate human health cancer risks and noncancer hazard indices for each receptor. A summary of the cancer risks and hazard indices for each receptor are presented in Tables 5-109 and 5-110, respectively.

The State of Wisconsin uses a risk level of 10^{-5} for evaluating cumulative cancer risks in the evaluation of sites under Chapter NR 700, while Superfund uses a risk level of 10^{-6} as the point at which risk management decisions may be considered. Risk management decisions most frequently made under Superfund are in the range of 10^{-6} to 10^{-4}. Wisconsin under Chapter NR 700 and EPA under Superfund both use an HI of 1.0 as a point at which risk management decisions may be considered.

Cancer risks exceeding 1.0×10^{-6} were identified for the recreational anglers, high-intake fish consumers, hunters, and drinking water users. Cancer risks for the marine construction worker slightly exceed the 1.0×10^{-6} level in the Little Lake

Butte des Morts Reach. Cancer risks as high as 3.8×10^{-3} were calculated for high-intake fish consumers, while risks as high as 2.8×10^{-3} were calculated for recreational anglers. These values are 46 and 34 times greater than the next highest risks calculated for any other receptor; the receptor with the next highest risks being the hunter with a risk of 8.3×10^{-5}. For the anglers, the cancer risks are driven by the ingestion of PCBs in fish tissue (over 80 percent for reaches of the Lower Fox River and over 68 percent in Green Bay). For the hunters, the cancer risks are driven by the ingestion of PCBs in waterfowl tissue. The risks to drinking water users exceed the 10^{-6} level only in the De Pere to Green Bay Reach (3.8×10^{-5}). This exceedance is due to arsenic, and the arsenic concentration used in the calculation is the value detected in one of four water samples from this reach. Arsenic was detected only once in the seven samples collected from the Lower Fox River, so it is quite possible that actual arsenic concentrations are lower than those used in this analysis; therefore, the risks associated with arsenic in this reach may be overstated. Additionally, the water in this reach is not currently used as a source of drinking water and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water).

Noncancer hazard indices exceeding 1.0 have been identified for the recreational anglers, high-intake fish consumers, hunters, drinking water users, and local residents. As noncancer hazard indices become greater than 1.0, the potential for adverse noncancer health effects becomes greater. While the hazard indices for the hunter, drinking water user, and local resident exceed 1.0, the maximum calculated hazard index for these receptors was 3.8, only slightly above 1.0. In comparison, noncancer hazard indices for anglers reached a maximum of 147, more than two orders of magnitude above 1.0. Exposure to PCBs in fish is responsible for over 86 percent of the hazard index for anglers in the Lower Fox River and over 88 percent of the hazard index for anglers in Green Bay. For the hunter, PCBs are responsible for over 95 percent of the total hazard index in the Lower Fox River and over 91 percent of the total hazard index in Green Bay.

Hazard indices for drinking water users and local residents exceeding 1.0 are due to mercury. The mercury surface water concentrations in the Lower Fox River database were obtained from a variety of sources that did not necessarily use analytical methods intended to quantitate low concentrations of this chemical. The study by Hurley *et al.* (1998) measured dissolved and total mercury in surface water from several locations on the Lower Fox River with much finer temporal resolution than the data included in the Lower Fox River database. When using more recent mercury data in the hazard index calculations for the drinking water user and local resident, the resulting hazard indices were below 1.0.

EPA guidance for risk characterization (EPA, 1995b, 1995c) indicates that an important step in the risk characterization process is the identification of subpopulations that may be highly exposed or highly susceptible. This evaluation of cancer risks and noncancer hazard indices indicates that the receptors with the highest risks and hazard indices are recreational anglers and high-intake fish consumers. Since calculated cancer risks exceed the 10^{-6} level by more than three orders of magnitude and calculated noncancer hazard indices exceed 1.0 by more than two orders of magnitude, the number of people included in these subpopulations is important to consider.

There are approximately 136,000 individuals with fishing licenses (WDNR, 1999d) living in counties adjacent to the Lower Fox River and Green Bay. The entire population of this area is estimated to be on the order of 640,000 (Census Bureau, 1992), which indicates that as many as 21 percent of the residents are active anglers. In addition to licensed anglers, their family members (who may not be anglers) can be exposed to PCBs in fish. The population of high-intake fish consumers, the most highly exposed subpopulation evaluated in this risk assessment, is estimated to be on the order of 5,000 people for the Lower Fox River and Green Bay area, including 3,800 low-income minority anglers, 1,200 Hmong anglers, and an unspecified number of Native American anglers.

For the recreational anglers and high-intake fish consumers, the exposure route of primary concern is ingestion of fish containing PCBs. The calculated cancer risks were as high as 2.8×10^{-3} for the recreational angler and 3.8×10^{-3} for the high-intake fish consumer, showing only small differences in these two groups of anglers. These calculated risks are over three orders of magnitude above the risk level of 10^{-6}. Put differently, the risks to the high-intake fish consumer represents a maximum incremental increased risk of contracting cancer in a lifetime of approximately four in 1,000 as a result of consuming fish caught from the Lower Fox River or Green Bay. The calculated noncancer hazard indices were as high as 107 for recreational anglers and 147 for the high-intake fish consumers, showing only small differences between these two groups of anglers. These values are more than 100 times the value established to protect people from long-term adverse noncancer health effects. As discussed in Section 5.6.2, the noncancer health effects associated with exposure to PCBs include reproductive effects (e.g., conception failure in highly-exposed women [Courval *et al.*, 1997]), developmental effects (e.g., neurological impairments in highly-exposed infants and children [Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996]), and immune system suppression (e.g., increased incidence of infectious disease in highly-exposed infants [Smith, 1984; Humphrey, 1988], effects on T-cell counts in adults and infants [Tryphonas, 1995; Weisglas-Kuperus *et al.*, 1995] or the possibility of increased susceptibility to infectious diseases in children exposed prenatally to PCBs and dioxins [Weisglas-Kuperus *et al.*, 2000]). All of these noncancer health effects are extensively documented in animal studies (ATSDR, 1997).

Population estimates for hunters are more difficult to define. The Wisconsin Department of Natural Resources estimated that there are approximately 3,000 individuals in Brown County with licenses to hunt waterfowl. Brown County encompasses the city of Green Bay and has a population of about 200,000 people (Census Bureau, 1992). Assuming that the same ratio of licenses to people applies elsewhere in the Green Bay to Lake Winnebago corridor where the overall population is 640,000 people (Census Bureau, 1992), the number of individuals licensed to hunt waterfowl in the Lower Fox River/Green Bay area is about 9,600 people. For the hunter, the exposure route of primary concern is the ingestion of waterfowl containing PCBs. The calculated risks for this receptor were as high as 8.3×10^{-5}, nearly two orders of magnitude above the risk level of 10^{-6}. This represents a maximum incremental increased risk of contracting cancer in a lifetime of one in 10,000 as a result of consuming hunted waterfowl. The hazard indices were as high as 3.1, which is about three times the value established to protect people from long-term adverse health effects. The noncancer health effects associated with exposure to PCBs for the hunter are similar to those described previously for recreational anglers and high-intake fish consumers.

Focused Risk Characterization

The baseline risk characterization, where cancer risks and noncancer hazard indices were calculated for a range of receptors, indicated that the receptors with the highest risks and hazard indices were recreational anglers and high-intake fish consumers due to exposure to PCBs in fish. Consequently, a focused evaluation of exposure to PCBs in fish by recreational anglers and high-intake fish consumers was performed. This focused evaluation included the following:

- A detailed evaluation of PCB fish data;
- Restatement of equations for calculating risks and hazard indices from fish ingestion and development of equations for calculating risk-based concentrations in fish;
- Development of intake assumptions for recreational anglers and high-intake fish consumers and restatement of toxicological parameters of PCBs;

- Calculation of cancer risks and noncancer hazard indices using a range of intake assumptions for recreational anglers and high-intake fish consumers and a variety of fish species;

- Evaluation of cancer risks and noncancer hazard indices using the intake assumptions for anglers in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al*., 1993);

- Summary of the probabilistic risk assessment for recreational anglers and high-intake fish consumers in Appendix B1;

- Summary of the evaluation of the risk assessment performed by Exponent (2000) on behalf of the Fox River Group;

- Qualitative and quantitative evaluation of PCB exposures to young children; and

- Calculation of risk-based concentrations in fish using the intake assumptions for recreational anglers and high-intake fish consumers, and the intake assumptions for anglers in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993).

This section summarizes the first item and the last six items in this list.

PCB Concentrations in Fish. As discussed in Section 2, an analysis of the trends in PCB concentrations in fish over time was performed and concentrations of PCBs in fish were shown to vary with time. In many cases, the concentrations in fish declined with time. In some cases, the concentrations remained essentially constant over time and in a few cases, the concentrations in fish appeared to increase.

For the risk analyses conducted, the concentrations of PCBs in fish are assumed to be constant over time. Such an approach is appropriately conservative and protective of human health. While it might be possible to predict future PCB concentrations in fish, there is substantial uncertainty in such projections. First, historical trends may not be accurate predictors of future trends. Second, the historical data is typically available for a period of 15 to 25 years, whereas the exposure periods of interest are 30 to 50 years. Thus, using historical data to predict future concentrations requires the additional assumption that the historical data will accurately reflect future concentrations over time periods that are two to three times longer than the historical time period. Third, there is not sufficient data to evaluate time trends in every species that people typically eat for every reach of the Lower Fox River and every zone of Green Bay.

Cancer Risks and Hazard Indices for Recreational Anglers and High-intake Fish Consumers. Cancer risks and hazard indices were calculated for recreational anglers and high-intake fish consumers in each reach of the Lower Fox River and each zone in Green Bay using a range of intake assumptions developed for these receptors. For recreational anglers, RME and CTE assumptions were developed from the 1989 and 1993 Michigan angler studies of West *et al.* (1989, 1993) and the 1989 Wisconsin angler study of Fiore *et al.* (1989). Intake assumptions based on the average of the intakes developed in the 1989 Michigan angler study and 1993 Michigan angler study were also developed. For high-intake fish consumers, three subpopulations were examined: low-income minority anglers, Native American anglers, and Hmong/Laotian anglers. RME and CTE assumptions were developed for each subpopulation. The cancer risks and hazard indices were calculated using the average concentrations of all fish samples, carp, perch, walleye, and white bass. The fish data from the 1990s in addition to walleye data in Green Bay from 1989 were used to calculate these concentrations.

Table 5-111 summarizes the cancer risks and hazard indices for the recreational anglers and high-intake fish consumers in the Lower Fox River and Green Bay. This table provides a lowest, median, and highest risk or hazard index. The "lowest" value does not represent the lowest possible risk or hazard index (which is zero, corresponding with eating no fish from the Lower Fox River or Green Bay), but represents the lowest value calculated using the intake assumptions provided for each angler group. Similarly, the "highest" value does not represent the highest possible risk or hazard index, but represents the highest value calculated with the intake assumptions provided for each angler group. Also provided in Table 5-111 are the cancer risks and hazard indices that result from using the concentration of PCBs in fish from Lake Winnebago in the risk and hazard index equations. These data from Lake Winnebago represent background concentrations.

The highest cancer risks based on all fish samples are for the RME scenario and are 9.8×10^{-4} for the recreational angler and 1.4×10^{-3} for the high-intake fish consumer, showing only small differences between these two groups of anglers. These values are three orders of magnitude above the 10^{-6} risk level. For the RME scenario, cancer risks range from 2.1×10^{-4} to 9.8×10^{-4} for the recreational angler and from 1.8×10^{-4} to 1.4×10^{-3} for the high-intake fish consumer. For the CTE scenario, the risks are four to eight times lower than the corresponding risks for the RME scenario. This variation reflects differences in intake assumptions and variations in fish concentrations by river reach and Green Bay zone. The highest calculated risks are for carp. The lowest, median, and average risk for carp are all higher than the corresponding values for all fish samples indicating that carp concentrations are systematically among the highest compared to other fish species. The risks calculated for perch, walleye, and white bass are grouped together as these species are among the most commonly sought-after fish by anglers. The highest risks in this group are always higher than the highest risks for all fish samples. The lowest risk is often lower than the lowest risk for all fish samples and the median risk is often similar to the median risk for all fish samples. This indicates that the PCB concentrations in these three species show more variation than the PCB concentrations in carp. The maximum risk of 9.8×10^{-4} for the recreational angler is about 21 times greater than the maximum risk of 4.6×10^{-5} calculated using the fish concentrations from Lake Winnebago, which represents background. The maximum risk of 1.4×10^{-3} for the high-intake fish consumer is also about 21 times greater than the maximum risk calculated with the average fish concentration from Lake Winnebago.

The highest hazard indices based on all fish samples are for the RME scenario and are 36.9 for recreational anglers and 52.0 for high-intake fish consumers, showing only small differences between these two groups of anglers. These values significantly exceed an HI of 1.0. The highest hazard indices are for carp, reaching 86.2 for recreational anglers and 121.5 for high-intake fish consumers. The maximum hazard indices of 36.9 for the recreational anglers and 52.0 for the high-intake fish consumers are approximately 21 times greater than the hazard indices calculated using the Lake Winnebago fish data for each receptor.

To show how risks and hazard indices vary by river reach and Green Bay zone, the maximum cancer risks and noncancer hazard indices calculated for recreational anglers and high-intake fish consumers in each reach of the Lower Fox River and each zone of Green Bay are provided in Table 5-112. These maximum risks and hazard indices were calculated using the average concentrations of all fish samples in the 1990s (plus walleye data from 1989 in Green Bay). In the Lower Fox River, the highest risks and hazard indices occur in the De Pere to Green Bay Reach, while the lowest risks and hazard indices occur in the Little Rapids to De Pere Reach. In Green Bay, the highest risks and hazard indices are in Zone 3A, while the lowest risks and hazard indices are in Zone 4.

Cancer Risks and Hazard Indices Associated with Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force. For additional perspective, cancer risks and hazard indices were also calculated using the exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). Intake assumptions were provided for four fish consumption scenarios: unlimited consumption, one meal per week, one meal per month, and six meals per year. The resulting cancer risks and hazard indices for each river reach and Green Bay zone were compared to results for recreational anglers and high-intake fish consumers. The cancer risks range from 3.2×10^{-5} to 2.7×10^{-3} and the hazard indices range from 0.8 to 67.8. The maximum cancer risks and hazard indices estimated for the unlimited consumption scenario are higher than the maximum risks and hazards for the high-intake fish consumers, although these values are comparable.

Summary of Probabilistic Risk Assessment. A probabilistic evaluation of exposure to PCBs in fish was provided in Appendix B1. This evaluation was prepared consistent with EPA guidance on probabilistic risk assessment (EPA, 1999), and supports and complements the point estimates of risks and hazard indices calculated in the focused evaluation of exposure to PCBs in fish.

The main results of the probabilistic evaluation are as follows.

- The deterministic CTE estimates of risk and hazard index provided in the focused evaluation are generally close to the means of the respective probability distributions of risk and hazard index. This is consistent with the interpretation of the CTE as the average risk or hazard index for the exposed population.

- The deterministic RME estimates of risk and hazard index provided in the focused evaluation are generally within the 90^{th} to 95^{th} percentiles of the respective probability distributions of risk and hazard indices. This is consistent with the interpretation provided in EPA (1999) of the RME as a plausible high-end risk or hazard index for the exposed population.

- The uncertainty in the estimate of the probability distributions of risk and hazard index is moderate, as reflected by the fact that the maximum and minimum values for the ranges are generally within a factor of 10 of each other.

Evaluation of Exponent Risk Assessment. The probabilistic risk assessment prepared by Exponent (2000) on behalf of the Fox River Group was evaluated in Appendix B1, and its assumptions were compared (wherever possible) to the results of the focused evaluation of exposure to PCBs in fish. This comparison could only be performed for recreational anglers, since Exponent (2000) did not evaluate exposures to high-intake fish consumers.

The comparison of Exponent (2000) assumptions with the assumptions used in the focused evaluation of recreational anglers was accomplished by calculating unit risks and unit hazard indices. These are the risks and hazard indices associated with unit concentrations of PCBs in fish (i.e., 1 mg/kg). This comparison indicated that the intake assumptions used by Exponent (2000) result in generally lower unit risks and hazard indices than the assumptions presented earlier in this section for recreational anglers. The differences between the unit risks and hazard indices calculated using Exponent (2000) assumptions and the assumptions presented earlier for recreational anglers depend on the study used to estimate fish intake assumptions. This difference is generally greatest for the survey of Michigan anglers by West *et al.* (1993), and least for the survey of Wisconsin anglers by Fiore *et al*. (1989).

Evaluation of PCB Exposure to Young Children. This section discussed potential health effects to young children from exposure to PCBs. This exposure includes transfer of PCBs from the mother across the placenta to the fetus, transfer from the mother to an infant through breast milk, and exposure to young children as a result of consuming contaminated fish. Transfer of maternal PCBs across the placenta and into breast milk can clearly result in significant exposures *in utero* and to a nursing infant (Dekoning and Karmaus, 2000). Exposure to PCBs in breast milk is estimated to be a major contributor to a child's body burden at 42 months of age (Lanting *et al.*, 1998) and to account for over 10 percent of an individual's cumulative PCB intake through 25 years of age (Patandin *et al.*, 1999). Two types of exposures to the mother were examined, short-term, high-level exposures and longer-term exposures to lower levels through fish ingestion.

The discussion of potential adverse health effects from short-term, high-level exposures relied on the adverse health effects observed in individuals from Taiwan and Japan who unknowingly ate cooking oil or rice oil contaminated with PCBs. These exposures resulted in an outbreak of short-term illnesses (including chloracne, a severe skin condition associated with high-level exposures to PCBs, dioxins, or furans), but also resulted in a variety of developmental, neurological, and immune system effects in the children born to women who suffered these exposures. These adverse health effects suggest that short-term, high-level exposures to PCBs (even one-time exposures) can have long-term consequences for the children born to women who suffer such exposures. It should be noted that the health effects reported in these studies could be associated with the presence of furans in the cooking oil and rice oil and not necessarily the presence of PCBs in this oil.

The discussion of potential adverse health effects from longer-term exposures to lower levels through fish ingestion indicated that such exposures also result in a variety of developmental, neurological, and immune system effects in the children born to women who suffered these exposures. No attempt was made to quantitatively evaluate such exposures, because methods to model exposures due to placental transfer or breast-feeding are not well established. However, since a variety of developmental, neurological, and immune system effects have been observed in infants and children whose mothers consumed fish known to be contaminated with PCBs, it seems plausible that PCB exposures for at least some women consuming fish from the Lower Fox River and Green Bay could be in the same range of PCB exposure levels at which these effects have been observed.

A quantitative evaluation of potential exposure to a young child (age 1 through 7 years) as a result of eating fish was performed. Chronic hazard indices were calculated for a recreational angler child and a high-intake fish consumer child for the Little Lake Butte des Morts and the De Pere to Green Bay reaches and the results were compared to results for the adult receptors in these reaches. A 7-year exposure period was chosen because this is the shortest period which is still considered chronic exposure (EPA, 1989c).

For the two reaches, the hazard indices estimated for the recreational angler children ranged from 29.7 to 88.4 for the RME scenario and from 9.1 to 19.3 for the CTE scenario. The hazard indices estimated for the high-intake fish consumer child ranged from 26.2 to 124.6 for the RME scenario and from 6 to 48.7 for the CTE scenario. In all cases, the calculated hazard indices are about 2.4 times greater for the child than for the adult.

Risk-based Concentrations in Fish. Using the range of intake assumptions for recreational anglers and high-intake fish consumers, a range of risk-based concentrations in fish were determined for specific cancer risk and hazard index levels. These risk-based concentrations were developed for cancer risks of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0 and are presented in Table 5-113. The risk-based fish concentrations for the recreational angler covered a range of about three orders of magnitude (1.4×10^{-3} mg/kg to 1.6 mg/kg). For a given set of assumptions, the risk-based fish concentration for an HI of 1.0 always fell between the risk-based fish concentrations for the 10^{-5} and 10^{-4} cancer risk levels. To be fully protective of recreational anglers from adverse noncancer effects, PCB concentrations in fish as low as 0.037 mg/kg are indicated. Similarly, the risk-based fish concentrations for the high-intake fish consumer(s) covered a range of about three orders of magnitude (9.8×10^{-4} mg/kg to 2.4 mg/kg) and the risk-based fish concentration for an HI of 1.0 always fell in between the risk-based fish concentrations for risk levels of 10^{-5} and 10^{-4}. To be fully protective of high-intake fish consumer(s) from adverse noncancer effects, PCB concentrations in fish as low as 0.026 mg/kg are indicated.

Risk-based fish concentrations were also calculated using the intake assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). Intake assumptions were provided for four fish consumption scenarios: unlimited consumption, one meal per week, one meal per month, and six meals per year. The resulting risk-based fish concentrations are provided in Table 5-113. These concentrations range from 5.0×10^{-4} mg/kg to 1.9 mg/kg, spanning more than three orders of magnitude depending on the selected cancer risk level and exposure scenario. The risk-based fish concentration for an HI of 1.0 is between the risk-based fish concentrations for cancer risks of 10^{-5} and 10^{-4}.

When Anderson *et al*. (1993) derived their risk-based fish concentration of 0.05 mg/kg for unlimited consumption, they used an RfD of 5.0×10^{-5} mg/kg-day based on a weight-of-evidence evaluation of epidemiological and animal studies, whereas the risk-based fish concentration in Table 5-113 of 0.02 mg/kg for an HI of 1.0 and unlimited consumption is based on the RfD of 2.0×10^{-5} mg/kg-day for Aroclor 1254.

It is interesting to note that the average of the RME risk-based fish concentrations for an HI of 1.0 for the recreational angler (0.063 mg/kg) and high-intake consumer (0.038 mg/kg) is also 0.05 mg/kg. The average value of 0.038 mg/kg for the high-intake fish consumer does not include the risk-based fish concentration for Hutchison (1999), since this study underestimates potential fish consumption in the Lower Fox River. The value of 0.05 mg/kg from Anderson *et al.* (1993) falls between the average RME and CTE risk-based fish concentrations at a 10^{-5} risk level for the recreational angler (0.024 to 0.14 mg/kg) and the high-intake fish consumer (0.014 to 0.078 mg/kg). The range of values for the high-intake fish consumer does not include the risk-based fish concentration based on the Hutchison (1999) study.

5.11.2 Conclusions

This risk assessment fulfills the NRC (2001) recommendation that sites be evaluated using a scientific risk-based framework so that different approaches for remediating PCB-contaminated submerged sediments can be compared in terms of the efficacy and human and ecological risks associated with each approach. The BLRA essentially evaluates risk assuming a no action remedial alternative. Relative risks associated with other potential remedial actions are discussed in the Feasibility Study.

This human health risk assessment for the Lower Fox River and Green Bay calculated cancer risks and noncancer hazard indices for the following receptors:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

The highest cancer risks and noncancer hazard indices were calculated for recreational anglers and high-intake fish consumers due primarily to consumption of fish containing PCBs. Using fish concentration data from 1990 on (and walleye data from 1989 in Green Bay), the cancer risks were as high as 9.8×10^{-4} for recreational anglers and 1.4×10^{-3} for high-intake fish consumers. These risks are more than 1,000 times greater than the 10^{-6} cancer risk level, which is the point at which risk management decisions may be made under Superfund. These risks are more than 100 times greater than the 10^{-5} cancer risk level used by Wisconsin in evaluating sites under Chapter NR 700.

The hazard indices were as high as 36.9 for the recreational angler and 52.0 for the high-intake fish consumer, far in exceedance of the value of 1.0 established to protect people from long-term adverse noncancer health effects. Noncancer hazard indices were also calculated for young children eating fish for the Little Lake Butte des Morts and De Pere to Green Bay reaches, the two reaches with the greatest population density. The hazard indices were approximately 2.4 times those found for adults or as high as 88.4 for children of recreational anglers and 124.6 for children of high-intake fish consumers. The noncancer health effects associated with exposure to PCBs include reproductive effects (Courval *et al.*, 1997), developmental effects (Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996; Johnson *et al.*, 1998a), and immunological effects (Smith, 1984; Humphrey, 1988; Tryphonas, 1995; Weisglas-Kuperus *et al.*, 1995, 2000). All of these noncancer health effects are extensively documented in animal studies (ATSDR, 1997). To provide perspective on the number of individuals who are potentially exposed, there are approximately 136,000 recreational anglers based on fishing licenses and approximately 5,000 high-intake fish consumers. The high-intake fish consumers include low-income minority anglers (about 3,800), Native American anglers (number is not known), and Hmong/Laotian anglers (about 1,200).

Cancer risks and hazard indices were calculated by river reach and Green Bay zone. However, there was relatively little difference between the highest risk in any reach or zone, which occurred in Green Bay Zone 3A, and the lowest risk in any reach or zone, which occurred in the Little Rapids to De Pere Reach. The risk in the De Pere to Green Bay Reach is 2.2 times greater than the risk in the Little Rapids to De Pere Reach.

The cancer risks and hazard indices were examined in detail in four species: carp, perch, walleye, and white bass. Carp consistently had the highest concentrations of PCBs in each reach, where data was available, and so exhibited the highest cancer risks and hazard indices. The lowest concentrations of PCBs occurred for perch, walleye, or white bass, depending on the river reach or Green Bay zone. The cancer risks and hazard indices for these three species are comparable.

The only other receptors with cancer risks exceeding 10^{-6} were the hunters and drinking water users. Cancer risks for the marine construction worker slightly exceed the 1.0×10^{-6} level in the Little Lake Butte des Morts Reach. The risks to the hunter were as high as 8.3×10^{-5}, but were at least 10 times lower than the risks to the anglers. The risk to the hunter was due to ingestion of PCBs in waterfowl. The risk to drinking water users exceeded 10^{-6} only in the De Pere to Green Bay Reach. This exceedance was due to arsenic in surface water and the arsenic value was from one detected value in a total of four samples. A more systematic sampling of this water for arsenic might show this single detected value to be anomalous. Additionally, the water in this reach is not currently used as a source of drinking water and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water). The cancer risks to drinking water users in all other reaches of the Lower Fox River and zones of Green Bay were below the 10^{-6} level, as were the cancer risks for the local residents and recreational water users (swimmers and waders).

The only other receptors with hazard indices exceeding 1.0 were the hunter, drinking water user, and local resident. The highest hazard index for these receptors was 3.8, only slightly above 1.0. These hazard indices are at least 38 times lower than the hazard indices for the anglers. The hazard indices were below 1.0 for the recreational water users and marine construction workers in all reaches of the Lower Fox River and zones of Green Bay.

Recreational anglers and high-intake fish consumers are at greatest risk for contracting cancer or experiencing noncancer health effects. The highest cancer risks are more than 20 times greater than background risks calculated for eating fish from Lake Winnebago (which is a background location relative to the Lower Fox River and Green Bay). The primary reason for these elevated risks and hazard indices is ingestion of fish containing PCBs.

5.12 Section 5 Figures and Tables

Section 5 figures and tables follow page 5-154 and include:

Figure 5-1. Potential Source Media, Chemical Migration Routes, Human Receptors, and Exposure Pathways

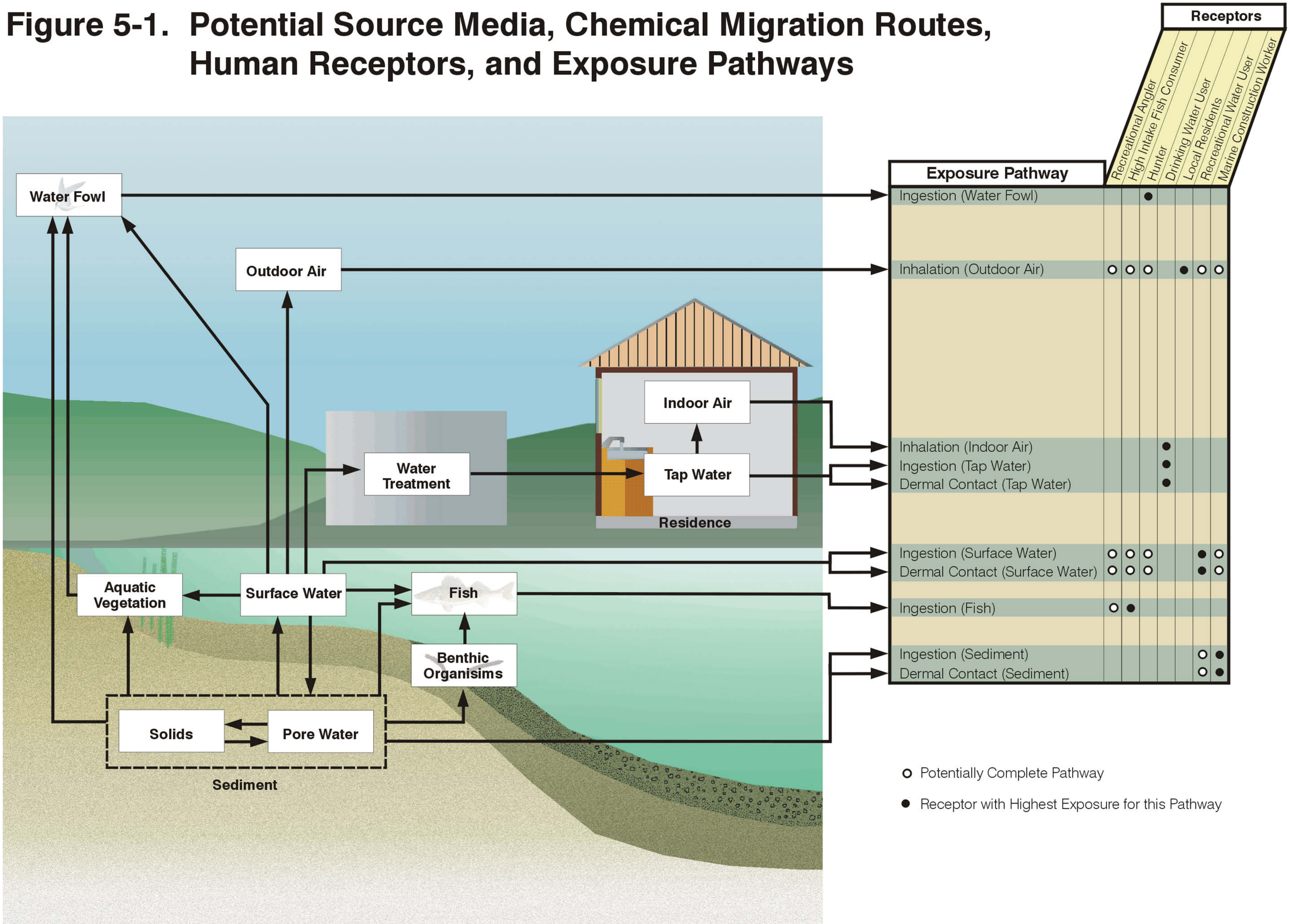
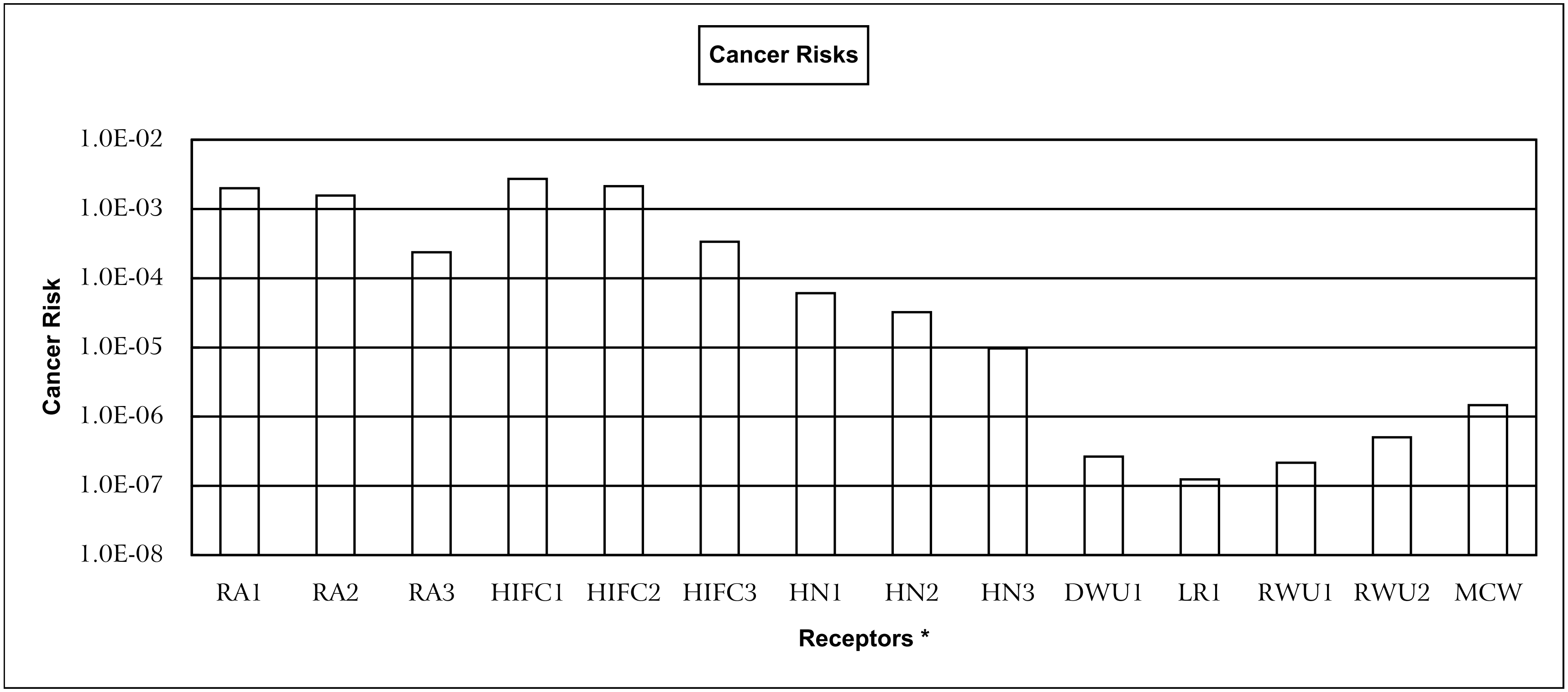
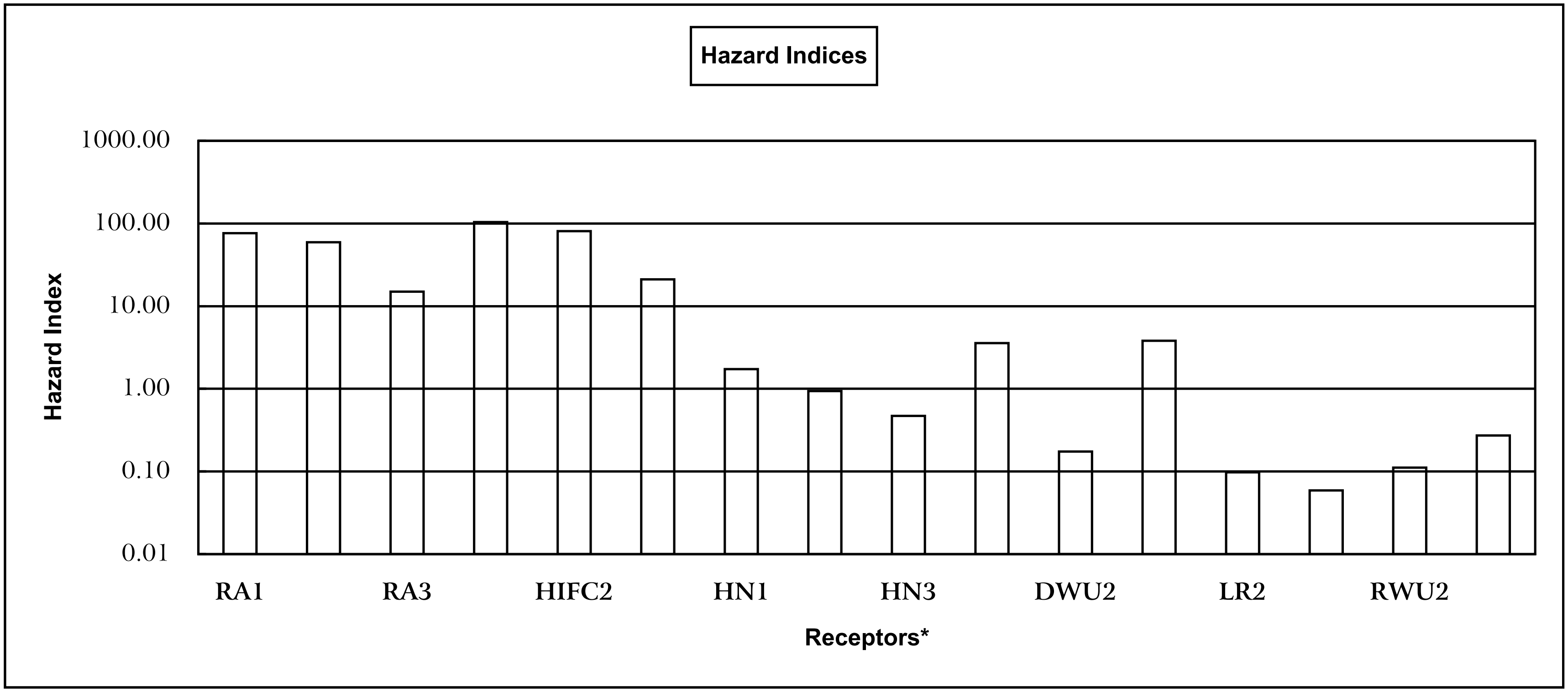


Figure 5-2 Cancer Risks for the Little Lake Butte des Morts Reach



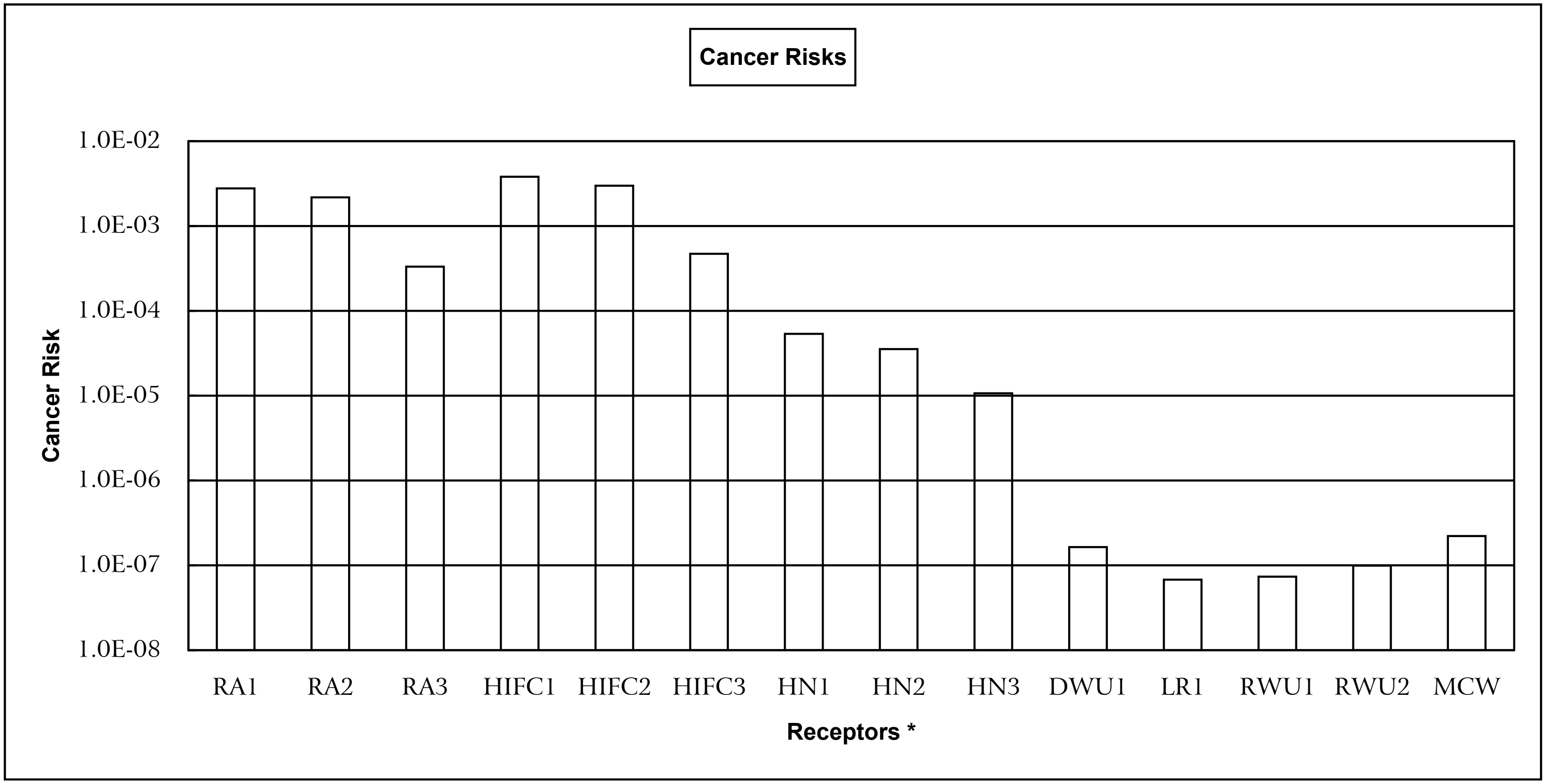
* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)		
RA2 - Recreational Angler (RME/Average)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA3 - Recreational Angler (CTE/Average)	HN2 - Hunter (RME/Average)	RWU1 - Swimmer (RME/Uppb)
HIFC1 - High-intake Fish Cons. (RME/Uppb)	HN3 - Hunter (CTE/Average)	RWU2 - Wader (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU1 - Drinking Water User (RME/Uppb)	MCW - Construction Worker (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		

Figure 5-3 Hazard Indices for the Little Lake Butte des Morts Reach



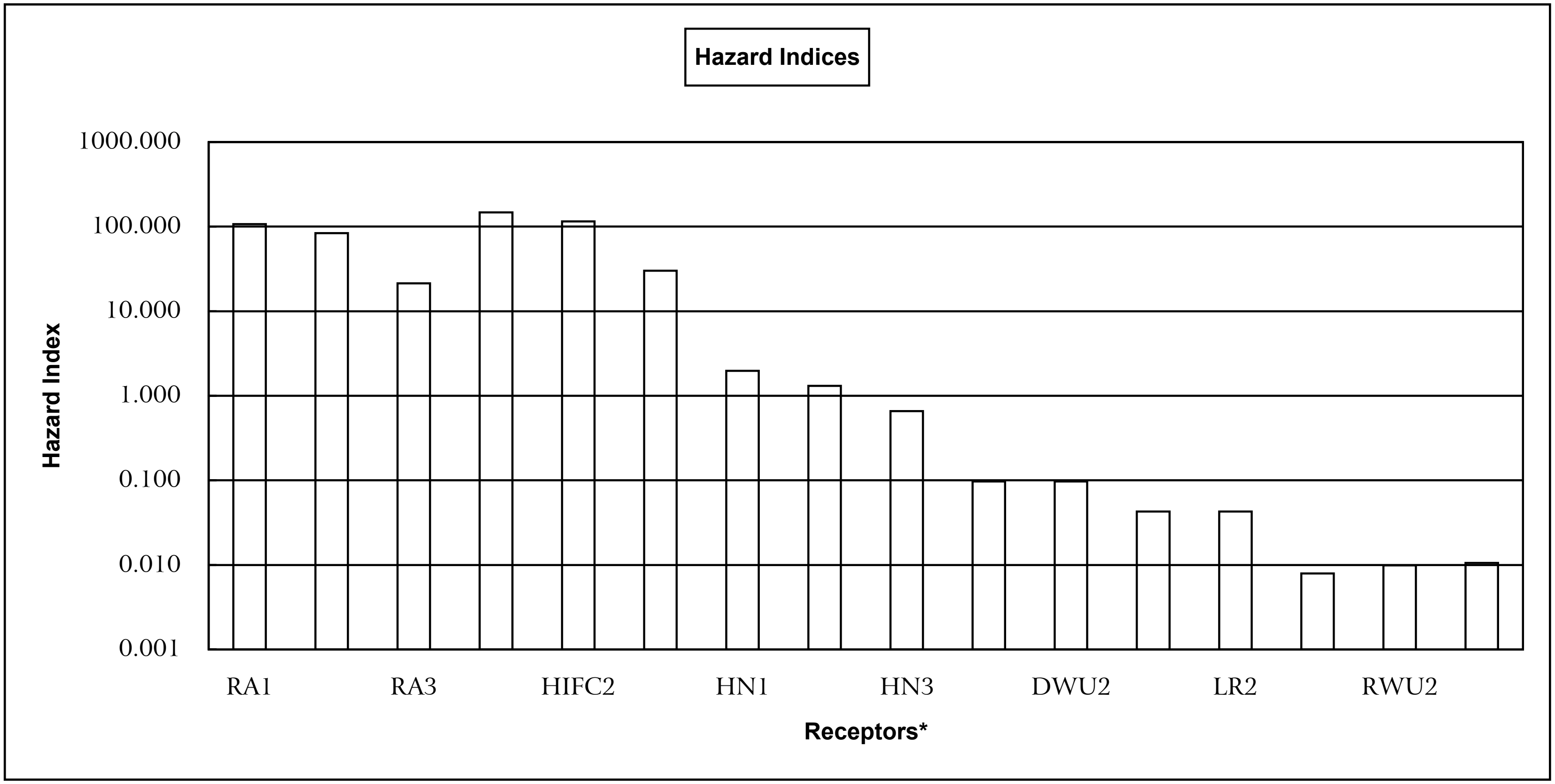
* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

Figure 5-4 Cancer Risks for the Appleton to Little Rapids Reach



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)		
RA2 - Recreational Angler (RME/Average)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA3 - Recreational Angler (CTE/Average)	HN2 - Hunter (RME/Average)	RWU1 - Swimmer (RME/Uppb)
HIFC1 - High-intake Fish Cons. (RME/Uppb)	HN3 - Hunter (CTE/Average)	RWU2 - Wader (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU1 - Drinking Water User (RME/Uppb)	MCW - Construction Worker (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		

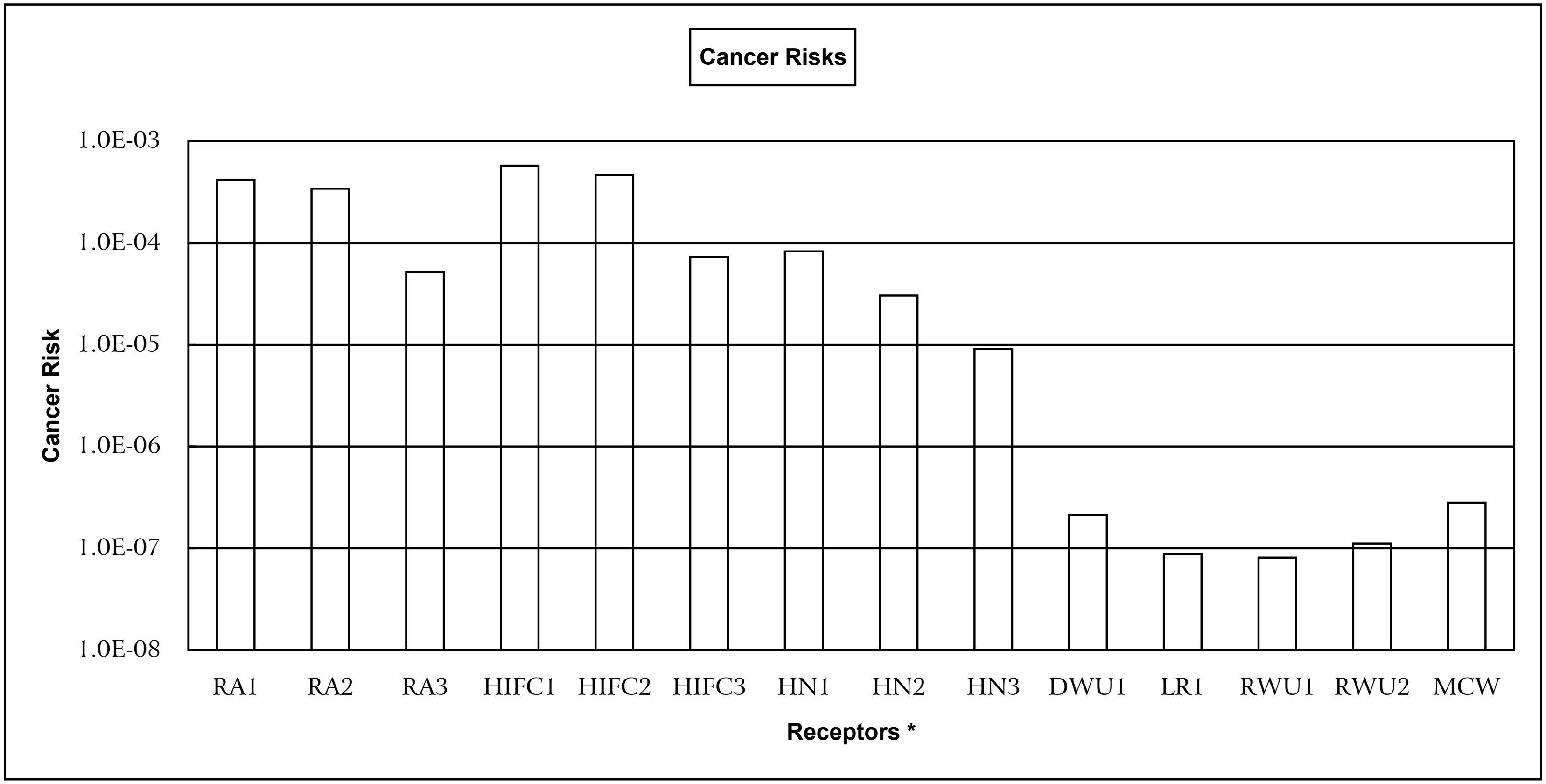
Figure 5-5 Hazard Indices for the Appleton to Little Rapids Reach



*** Key for Receptors**

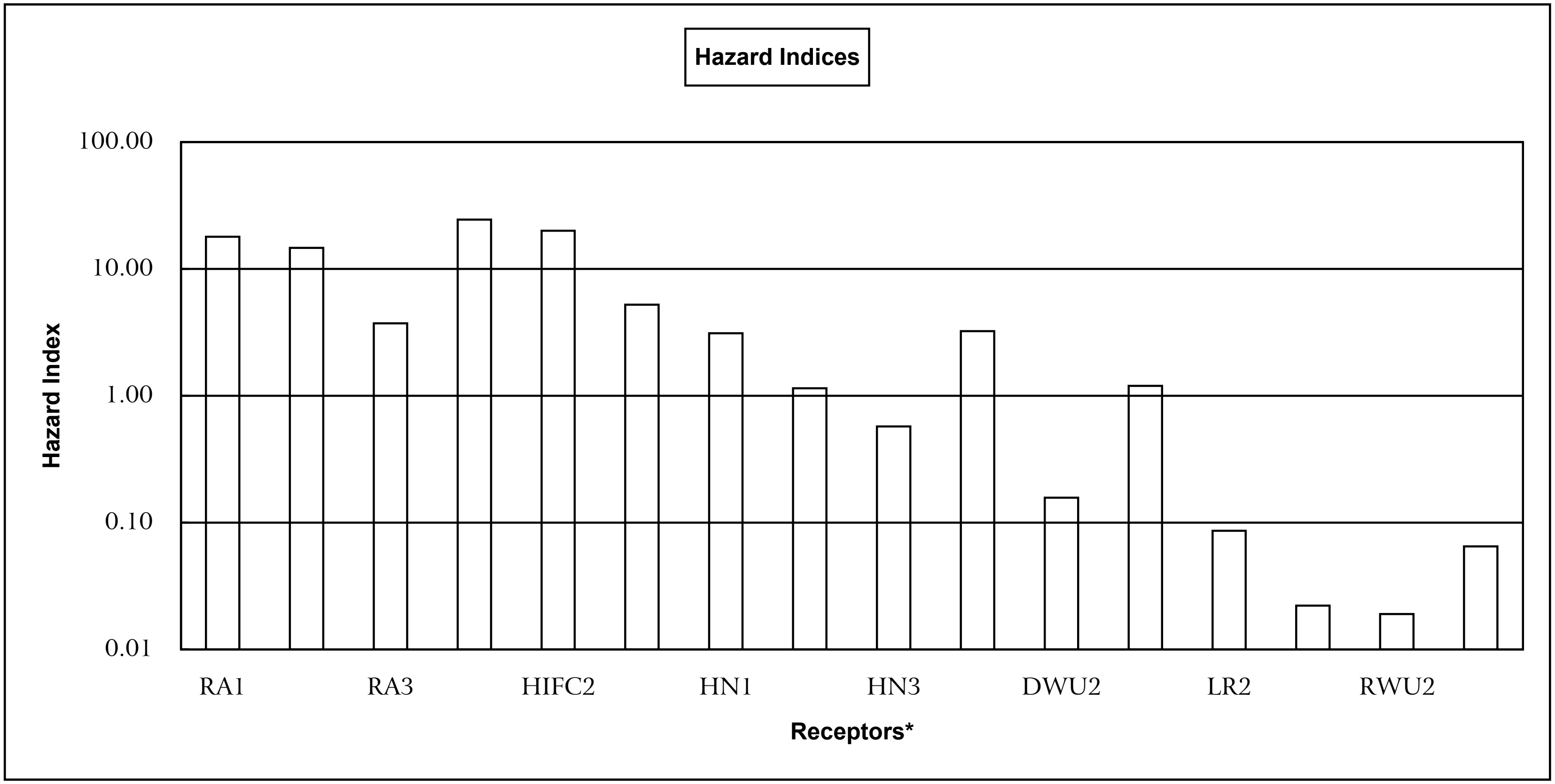
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

Figure 5-6 Cancer Risks for the Little Rapids to De Pere Reach



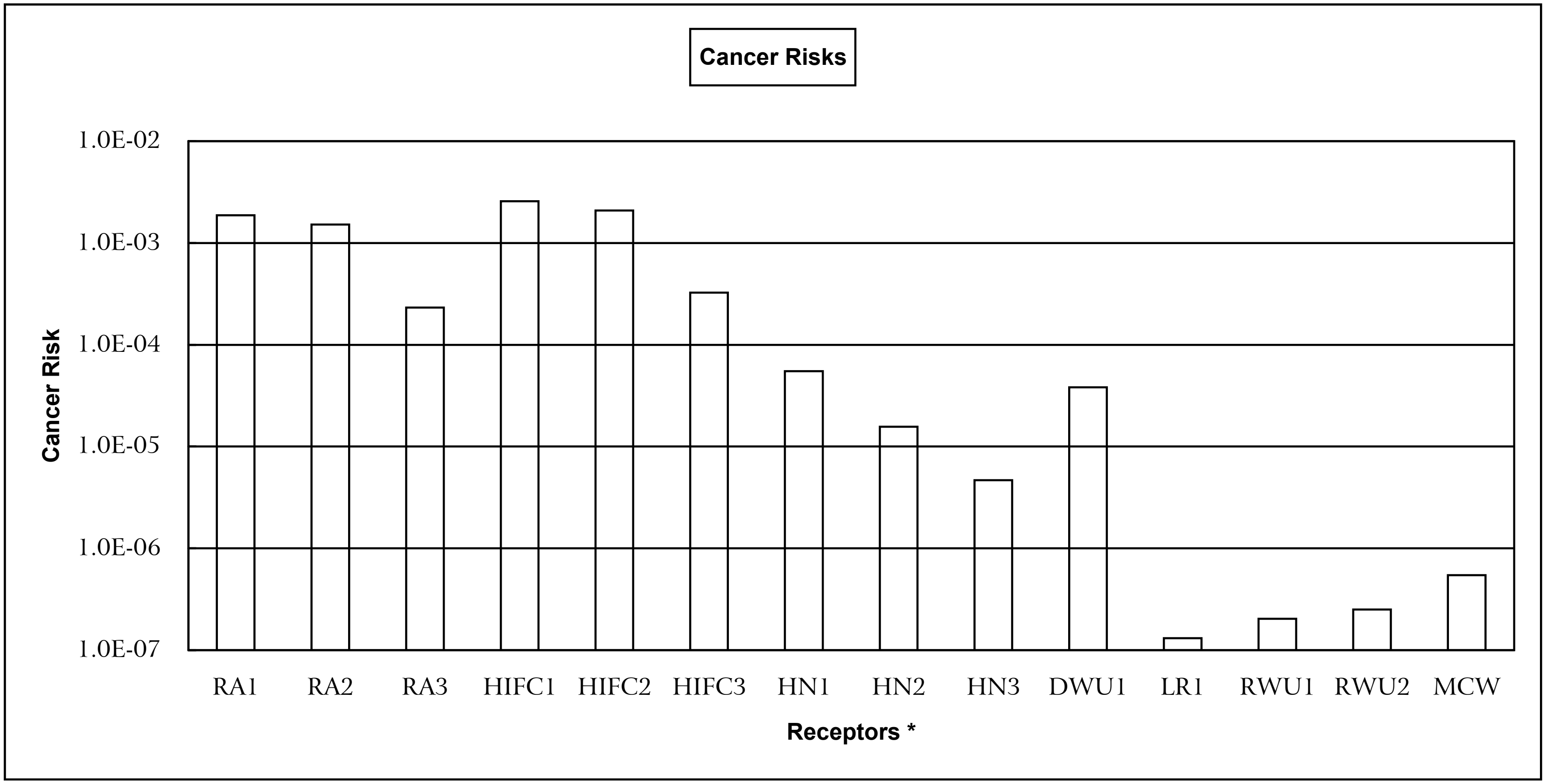
* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)		
RA2 - Recreational Angler (RME/Average)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA3 - Recreational Angler (CTE/Average)	HN2 - Hunter (RME/Average)	RWU1 - Swimmer (RME/Uppb)
HIFC1 - High-intake Fish Cons. (RME/Uppb)	HN3 - Hunter (CTE/Average)	RWU2 - Wader (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU1 - Drinking Water User (RME/Uppb)	MCW - Construction Worker (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		

Figure 5-7 Hazard Indices for the Little Rapids to De Pere Reach



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

Figure 5-8 Cancer Risks for the De Pere to Green Bay Reach



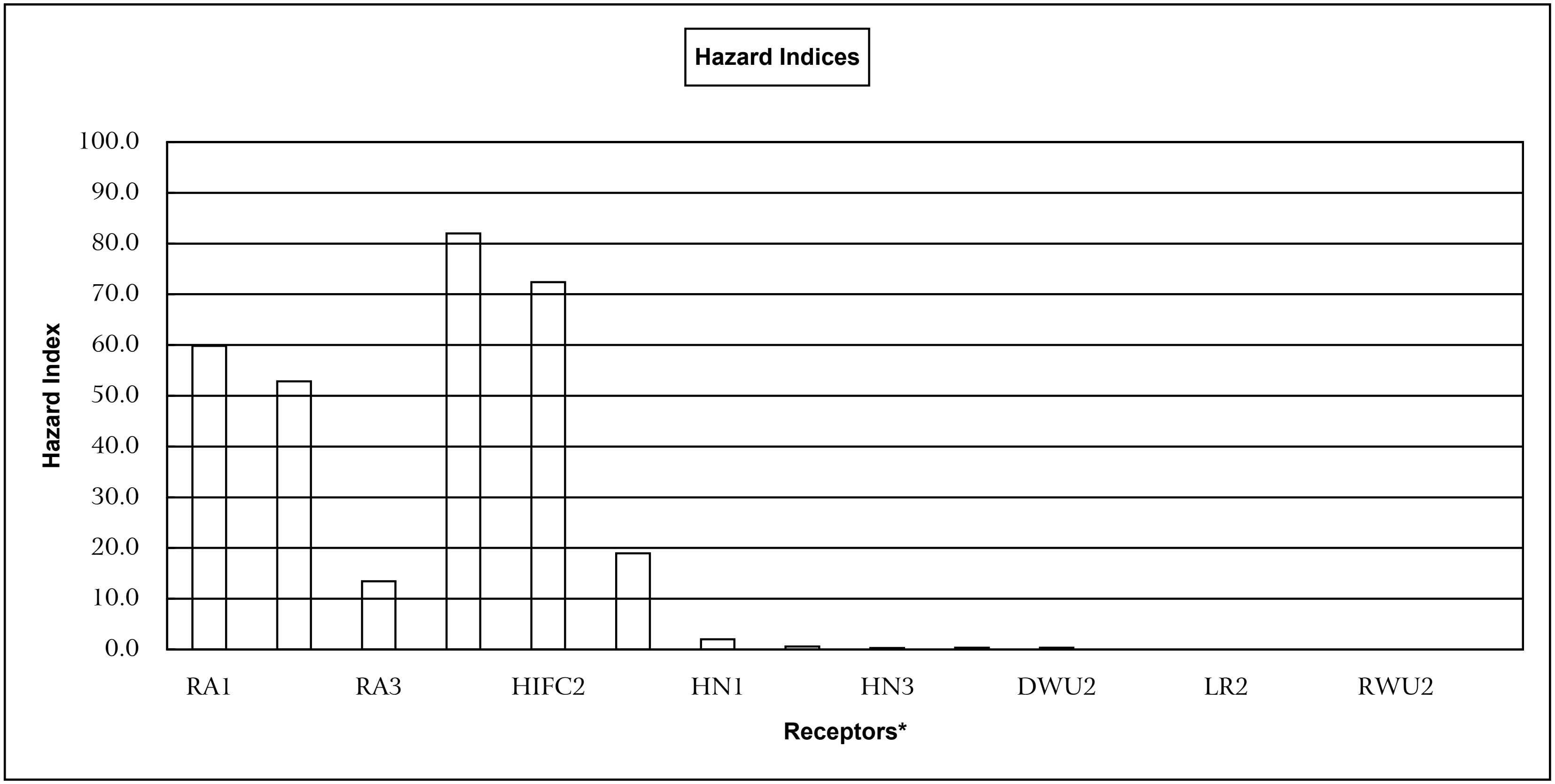
*** Key for Receptors**

RA1 - Recreational Angler (RME/Uppb)
RA2 - Recreational Angler (RME/Average)
RA3 - Recreational Angler (CTE/Average)
HIFC1 - High-intake Fish Cons. (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)
HIFC3 - High-intake Fish Cons. (CTE/Average)

HN1 - Hunter (RME/Uppb)
HN2 - Hunter (RME/Average)
HN3 - Hunter (CTE/Average)
DWU1 - Drinking Water User (RME/Uppb)

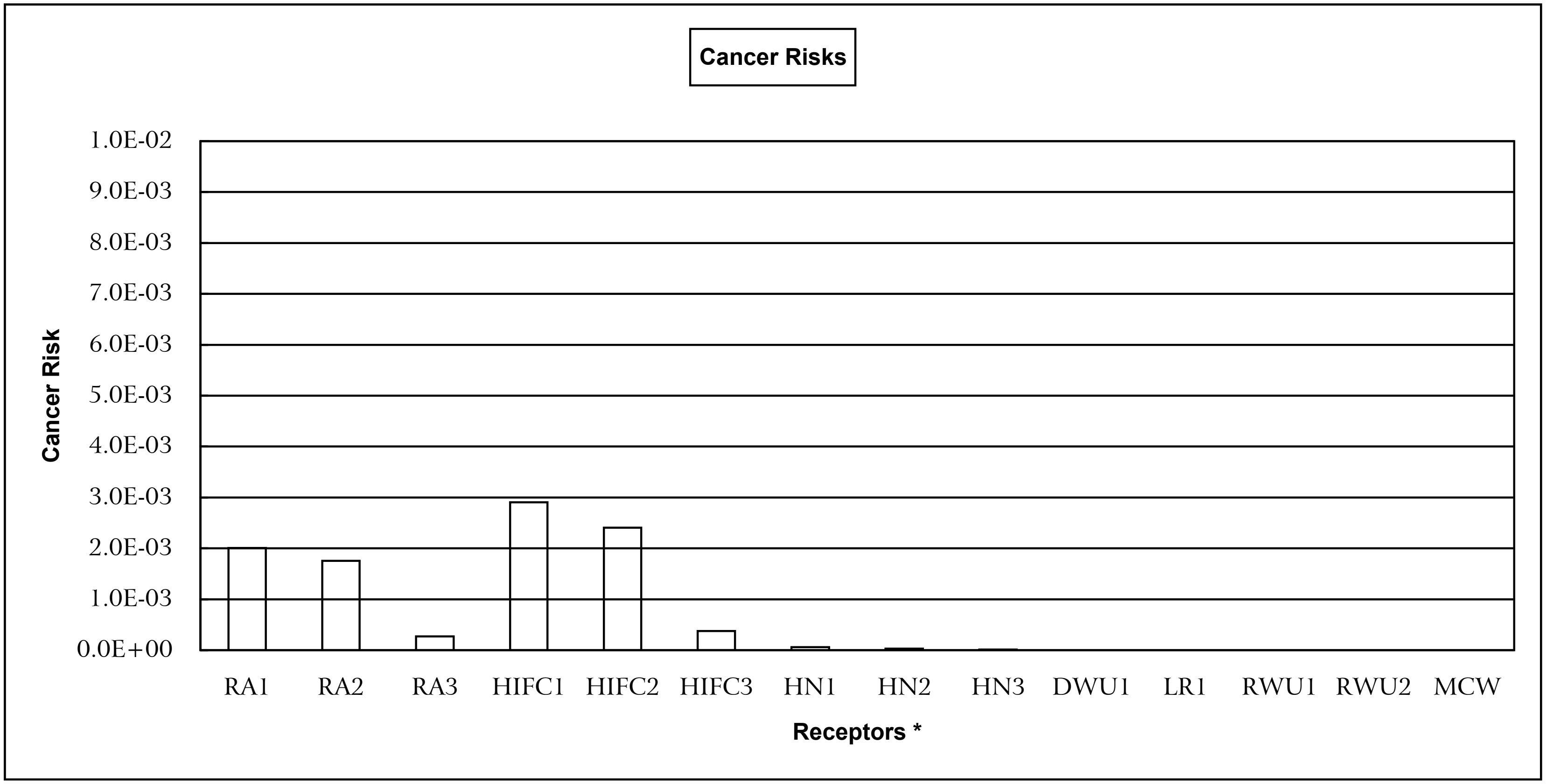
LR1 - Local Resident (RME/Uppb)
RWU1 - Swimmer (RME/Uppb)
RWU2 - Wader (RME/Uppb)
MCW - Construction Worker (RME/Uppb)

Figure 5-9 Hazard Indices for the De Pere to Green Bay Reach



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

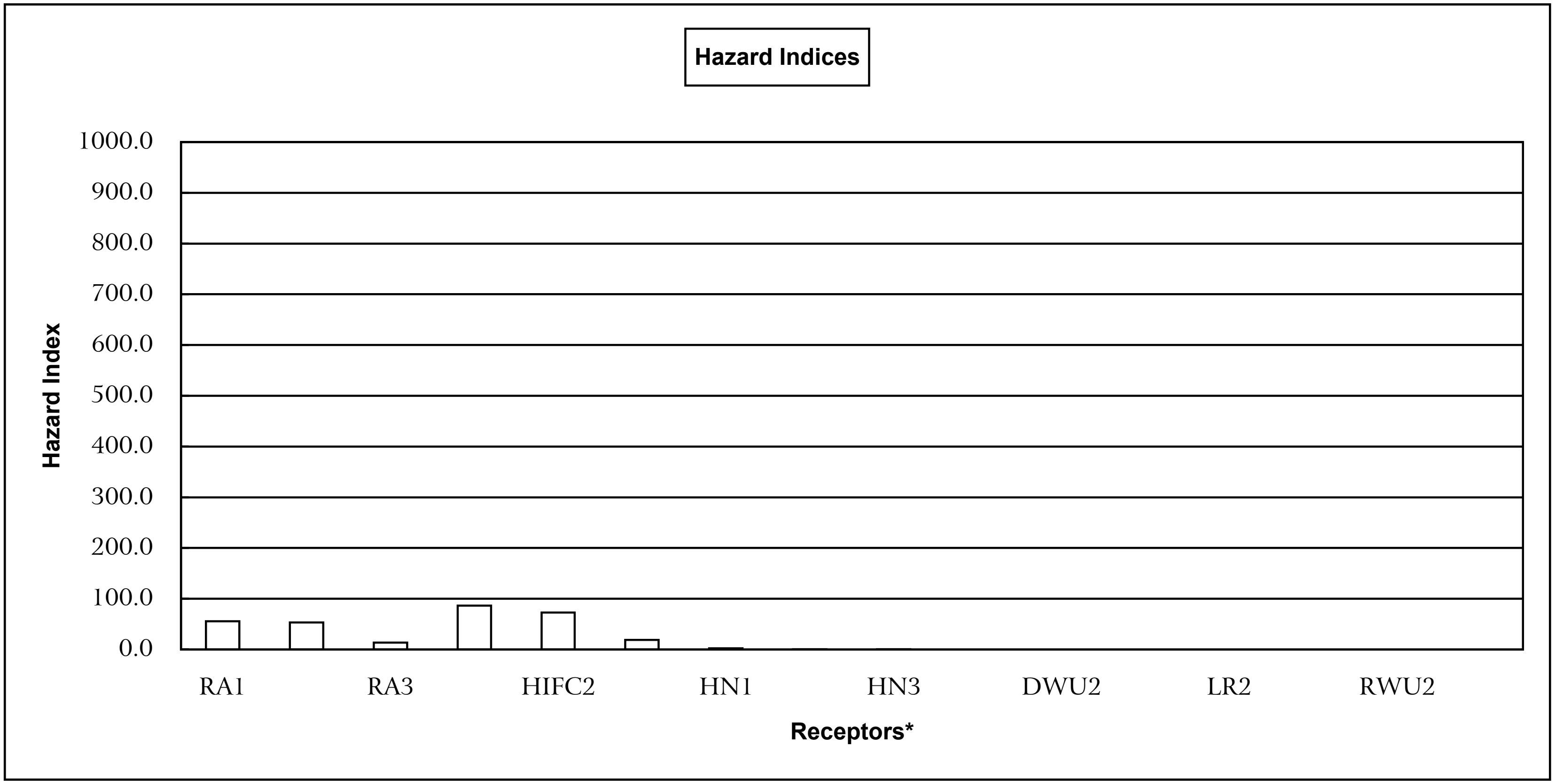
Figure 5-10 Cancer Risks for Green Bay



*** Key for Receptors**

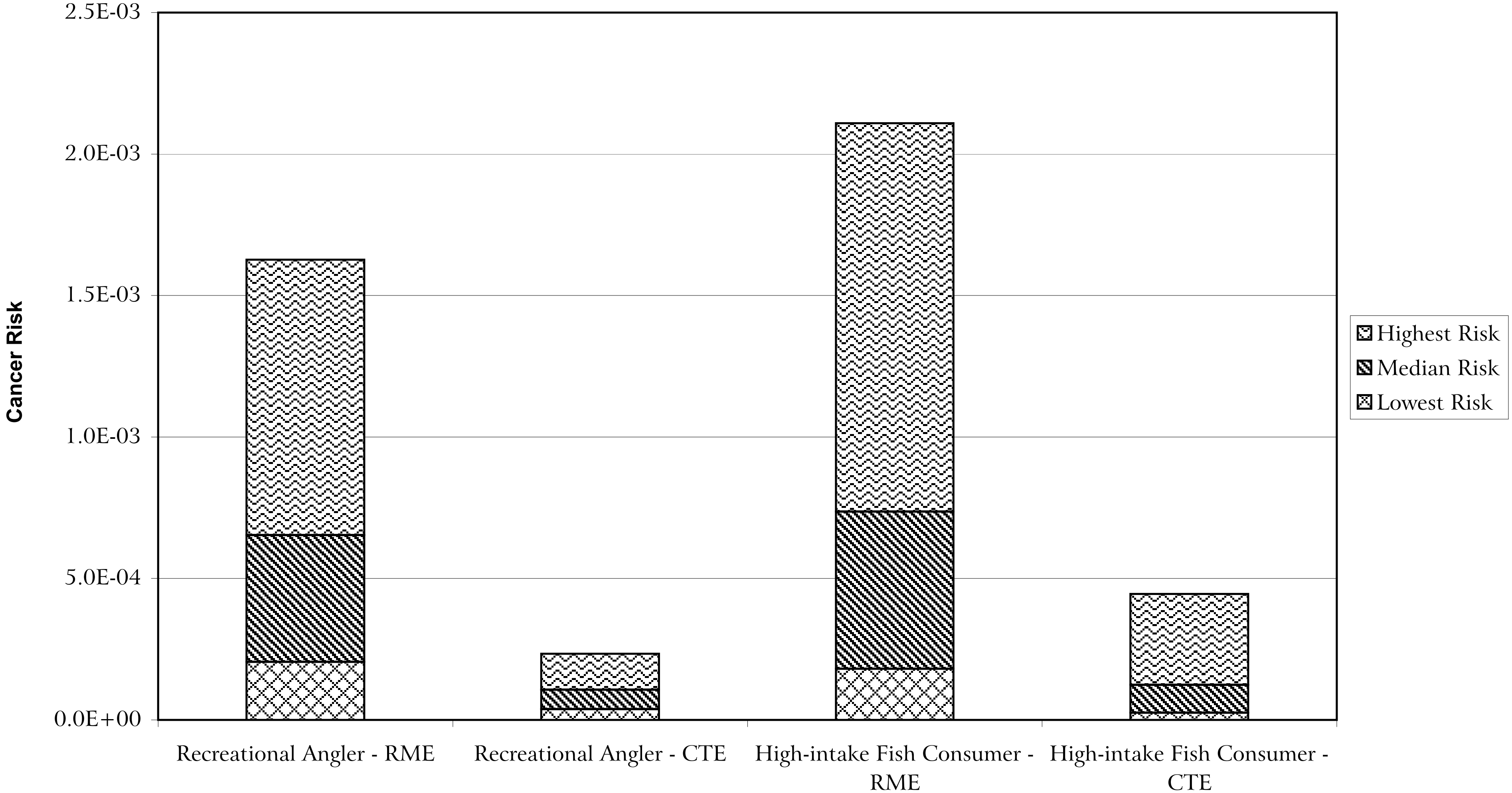
RA1 - Recreational Angler (RME/Uppb)		
RA2 - Recreational Angler (RME/Average)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA3 - Recreational Angler (CTE/Average)	HN2 - Hunter (RME/Average)	RWU1 - Swimmer (RME/Uppb)
HIFC1 - High-intake Fish Cons. (RME/Uppb)	HN3 - Hunter (CTE/Average)	RWU2 - Wader (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU1 - Drinking Water User (RME/Uppb)	MCW - Construction Worker (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		

Figure 5-11 Hazard Indices for Green Bay



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

Figure 5-12 Range of Cancer Risks for Recreational Anglers and High-intake Fish Consumers in the Lower Fox River



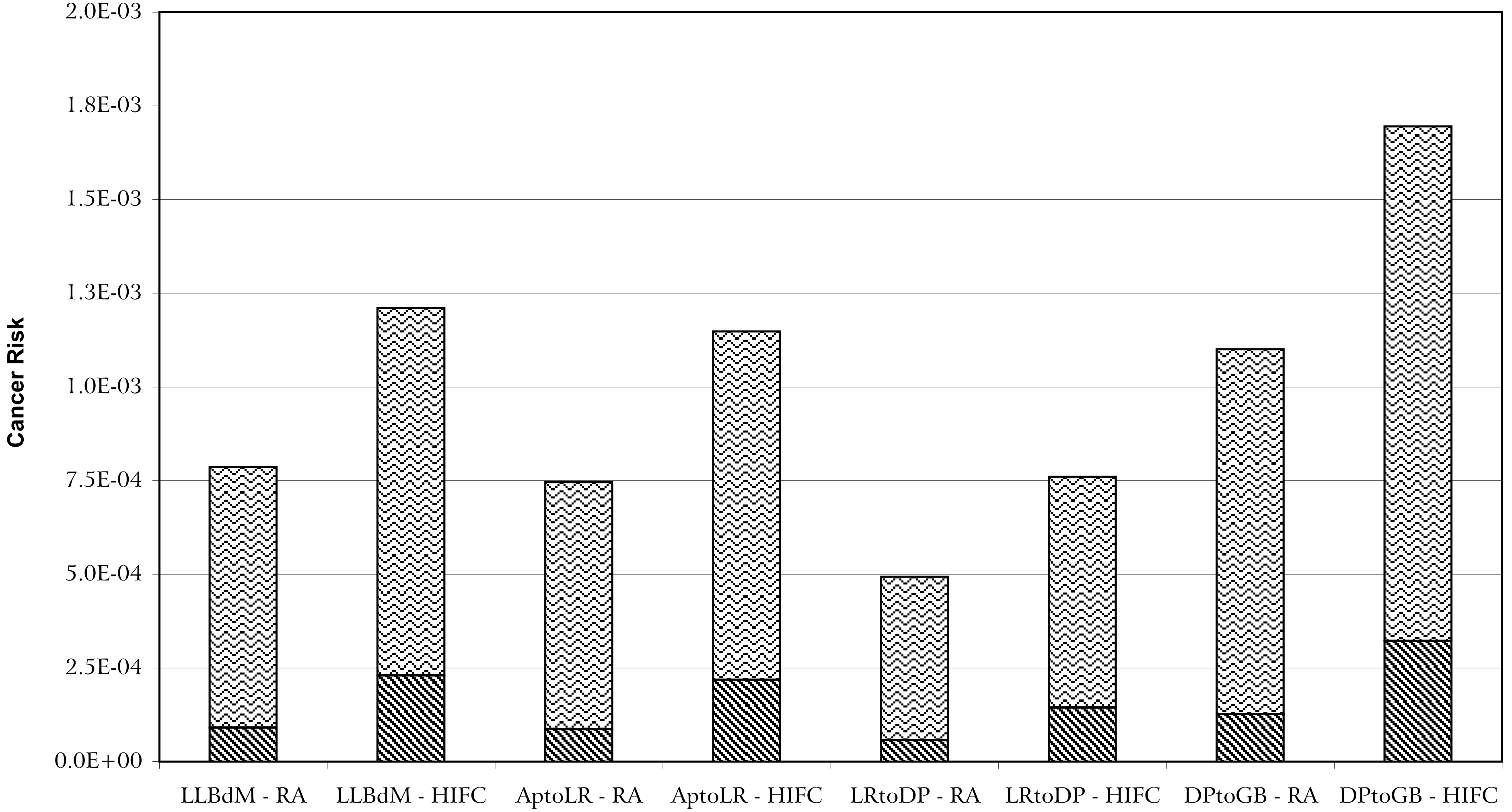
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-13 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers in the Lower Fox River

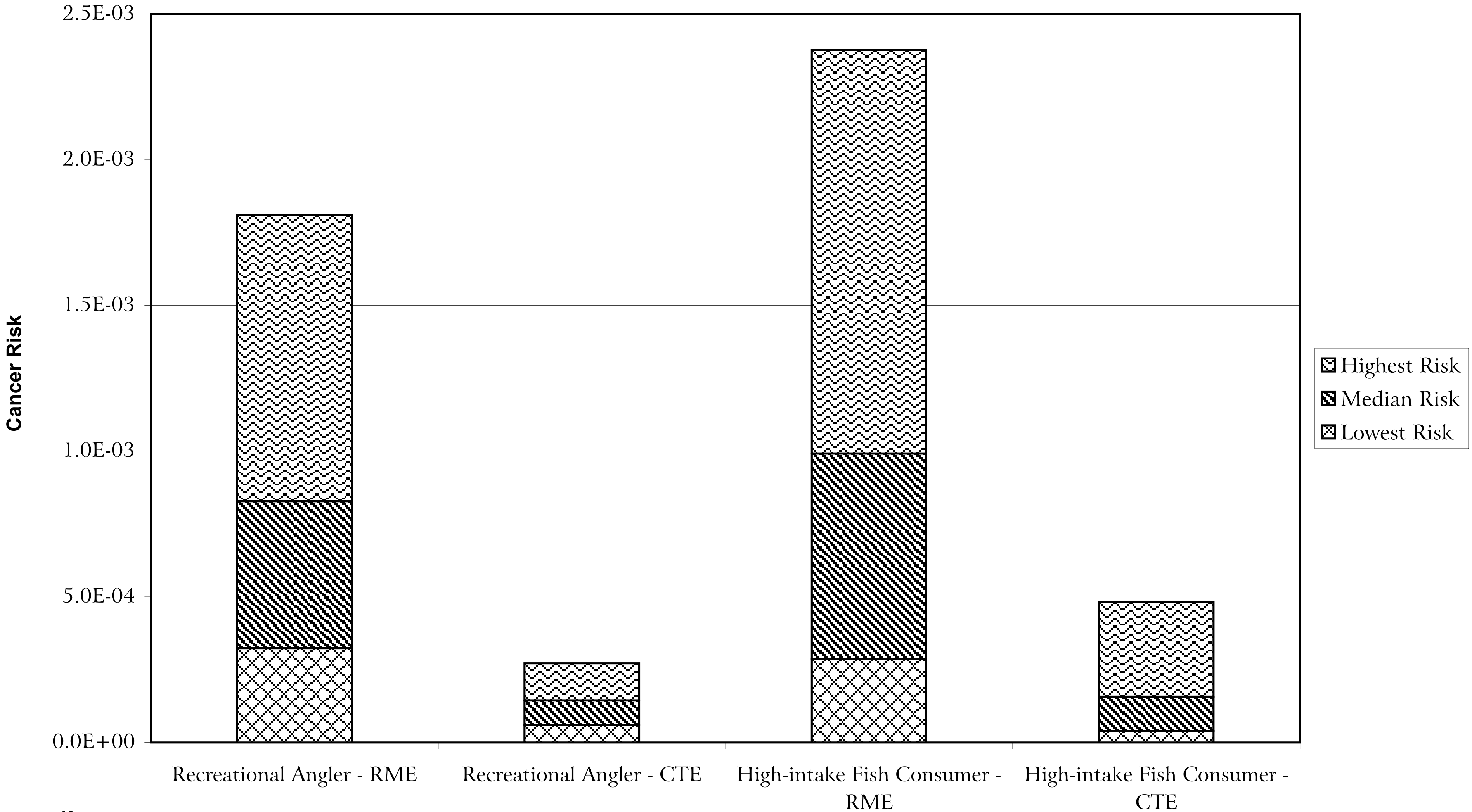


Key:

AptoLR - Appleton to Little Rapids
CTE - Central Tendency Exposure
DPtoGB - De Pere to Green Bay
HIFC - High-intake Fish Consumer
LLBdM - Little Lake Butte des Morts
LRtoDP - Little Rapids to De Pere
RA - Recreational Angler
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-14 Range of Cancer Risks for Recreational Anglers and High-intake Fish Consumers in Green Bay



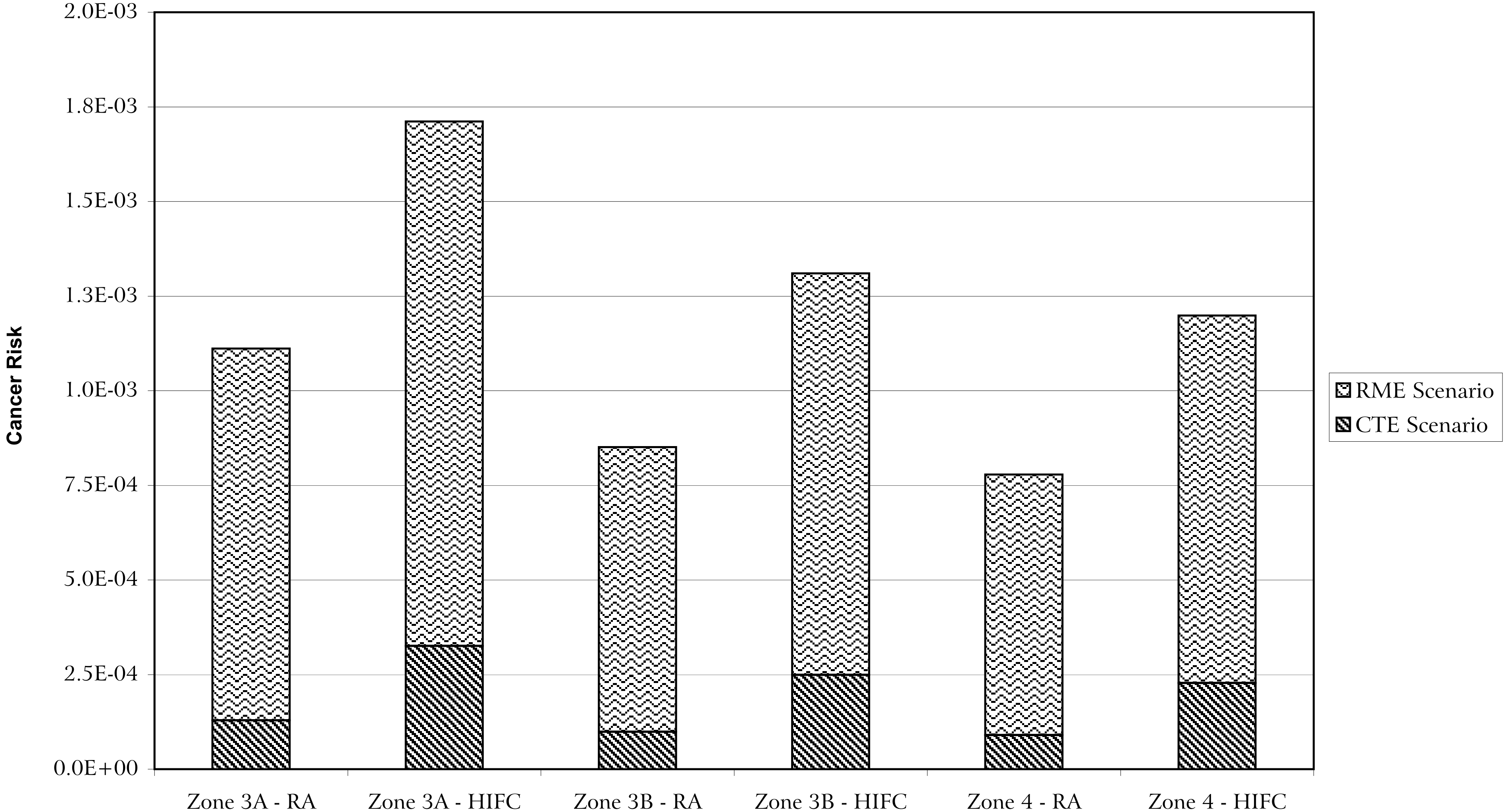
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s plus walleye samples in 1989.

Figure 5-15 Maximum Cancer Risks for Recreational Anglers and High-intake Fish Consumers by Zone in Green Bay

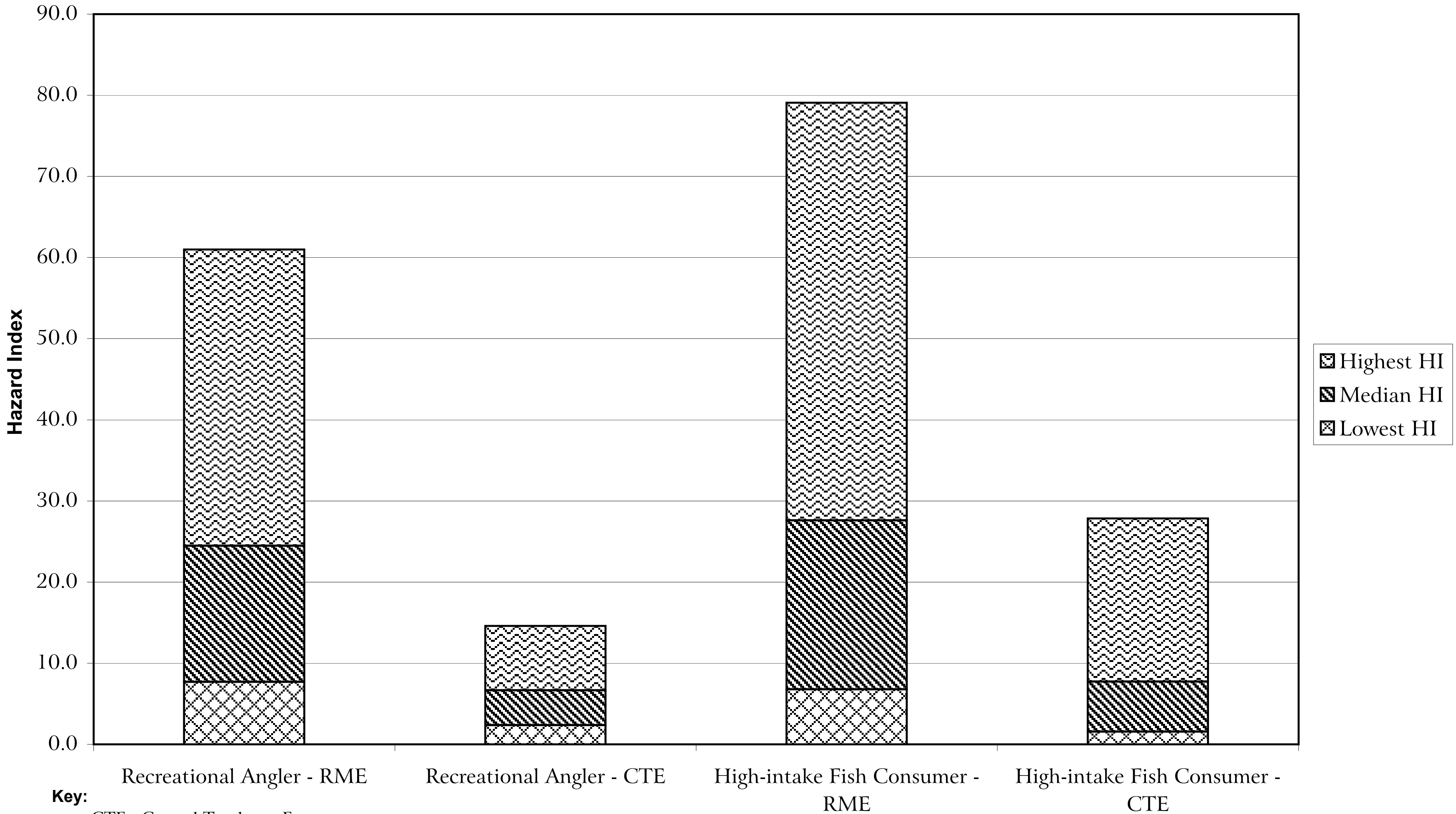


Key:

CTE - Central Tendency Exposure
RA - Recreational Angler
HIFC - High-intake Fish Consumer
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s plus walleye samples in 1989.

Figure 5-16 Range of Hazard Indices for Recreational Anglers and High-intake Fish Consumers in the Lower Fox River



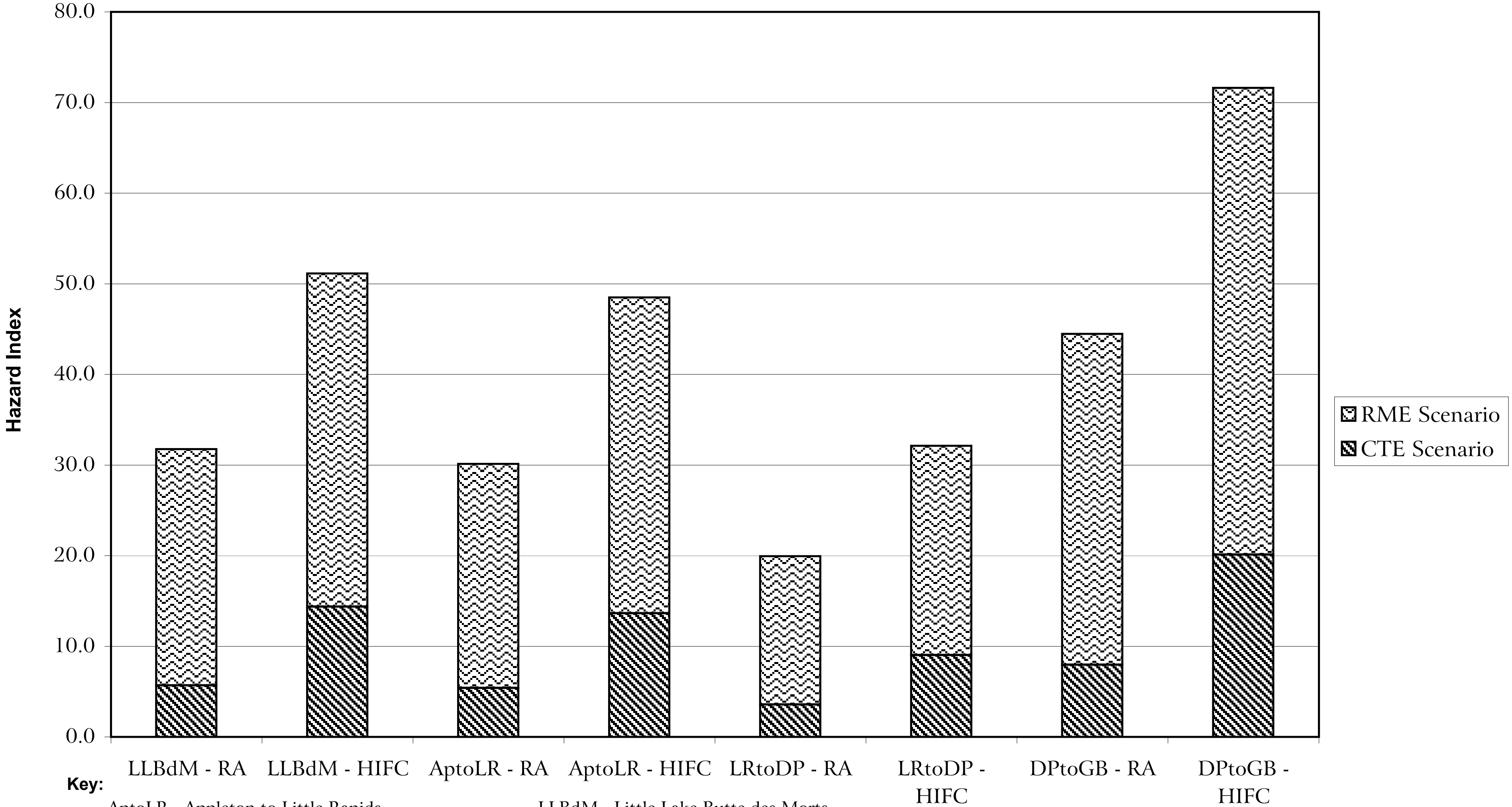
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-17 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers by Reach in the Lower Fox River

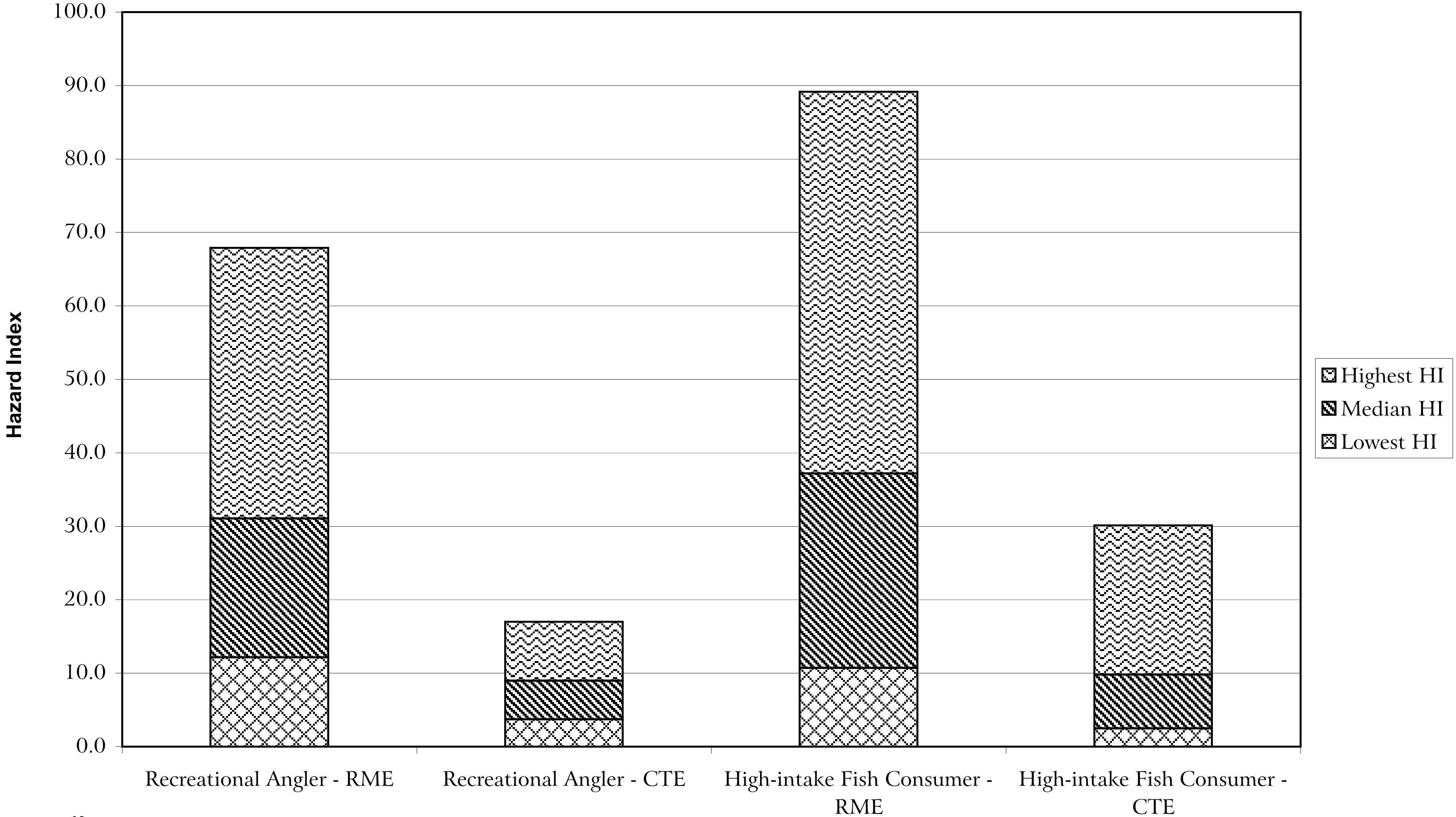


Key:

AptoLR - Appleton to Little Rapids
CTE - Central Tendency Exposure
DPtoGB - De Pere to Green Bay
HIFC - High-intake Fish Consumer
LLBdM - Little Lake Butte des Morts
LRtoDP - Little Rapids to De Pere
RA - Recreational Angler
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-18 Range of Hazard Indices for Recreational Anglers and High-intake Fish Consumers in Green Bay



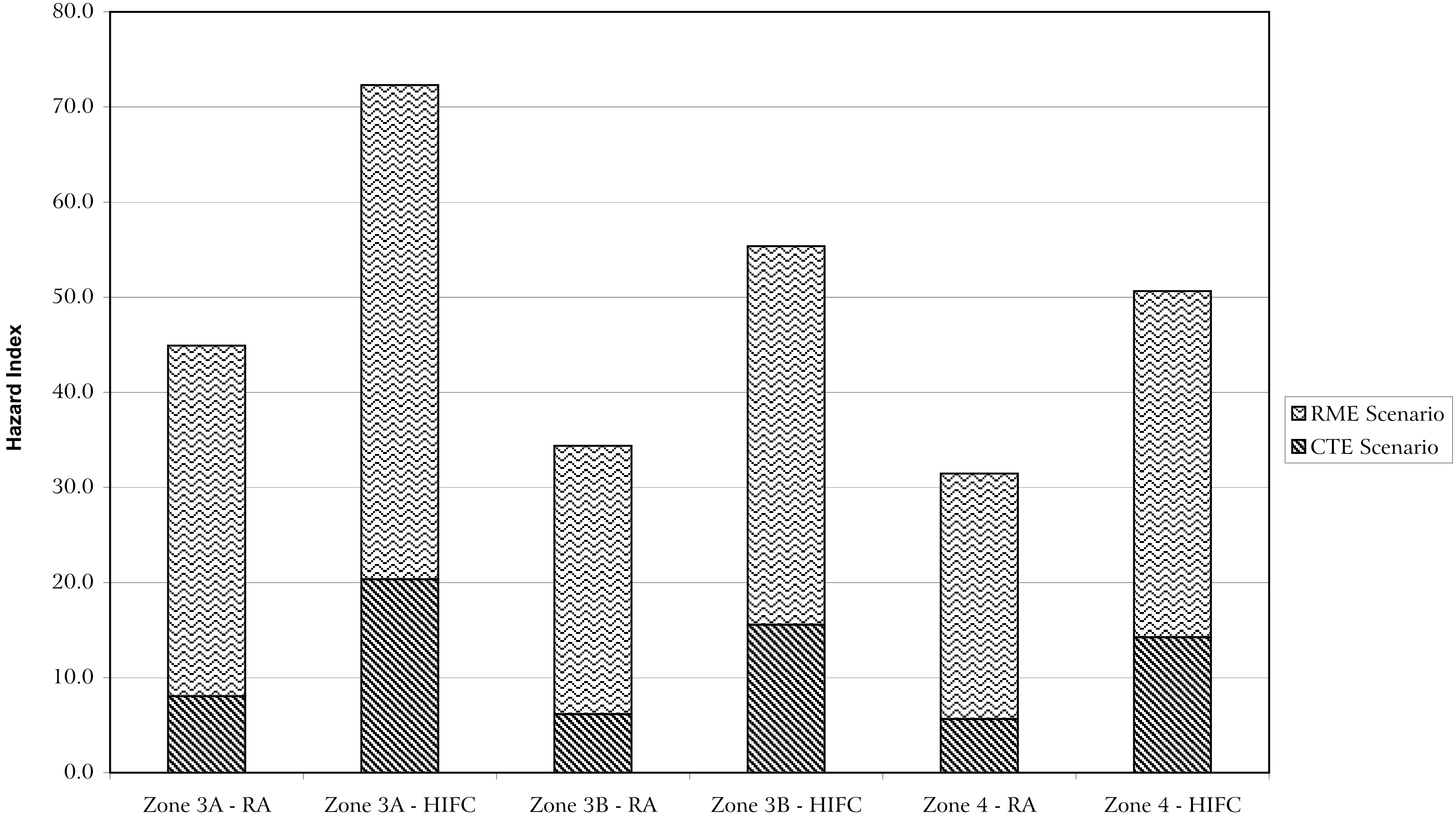
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-19 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers by Zone in Green Bay



Key:

CTE - Central Tendency Exposure
RA - Recreational Angler
HIFC - High-intake Fish Consumer
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s plus walleye samples in 1989.

Figure 5-20 Comparison of CTE and RME Risk Values with Distribution Data - Little Lake Butte des Morts Reach

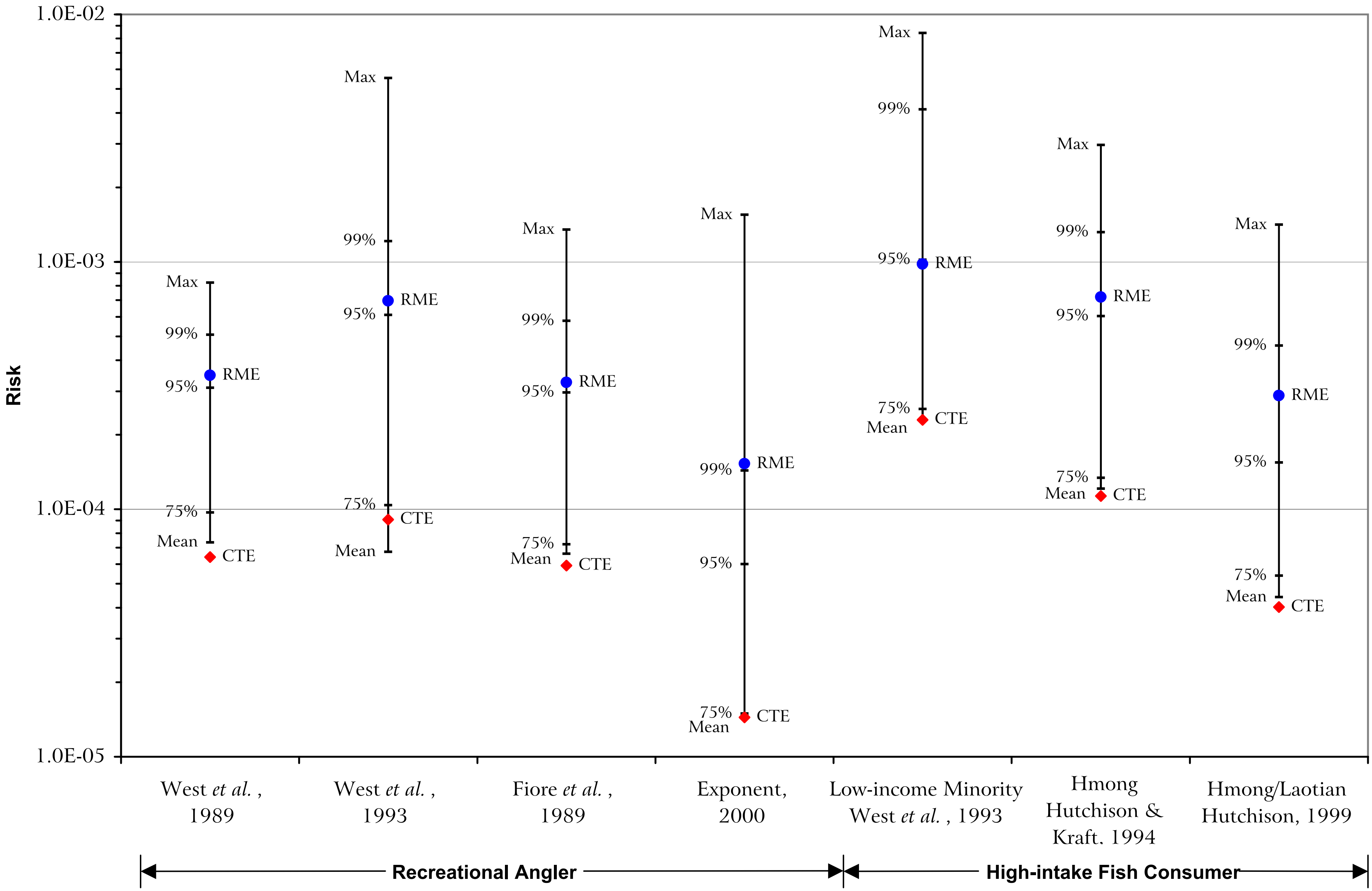


Figure 5-21 Comparison of CTE and RME Hazard Index Values with Distribution Data - Little Lake Butte des Morts Reach

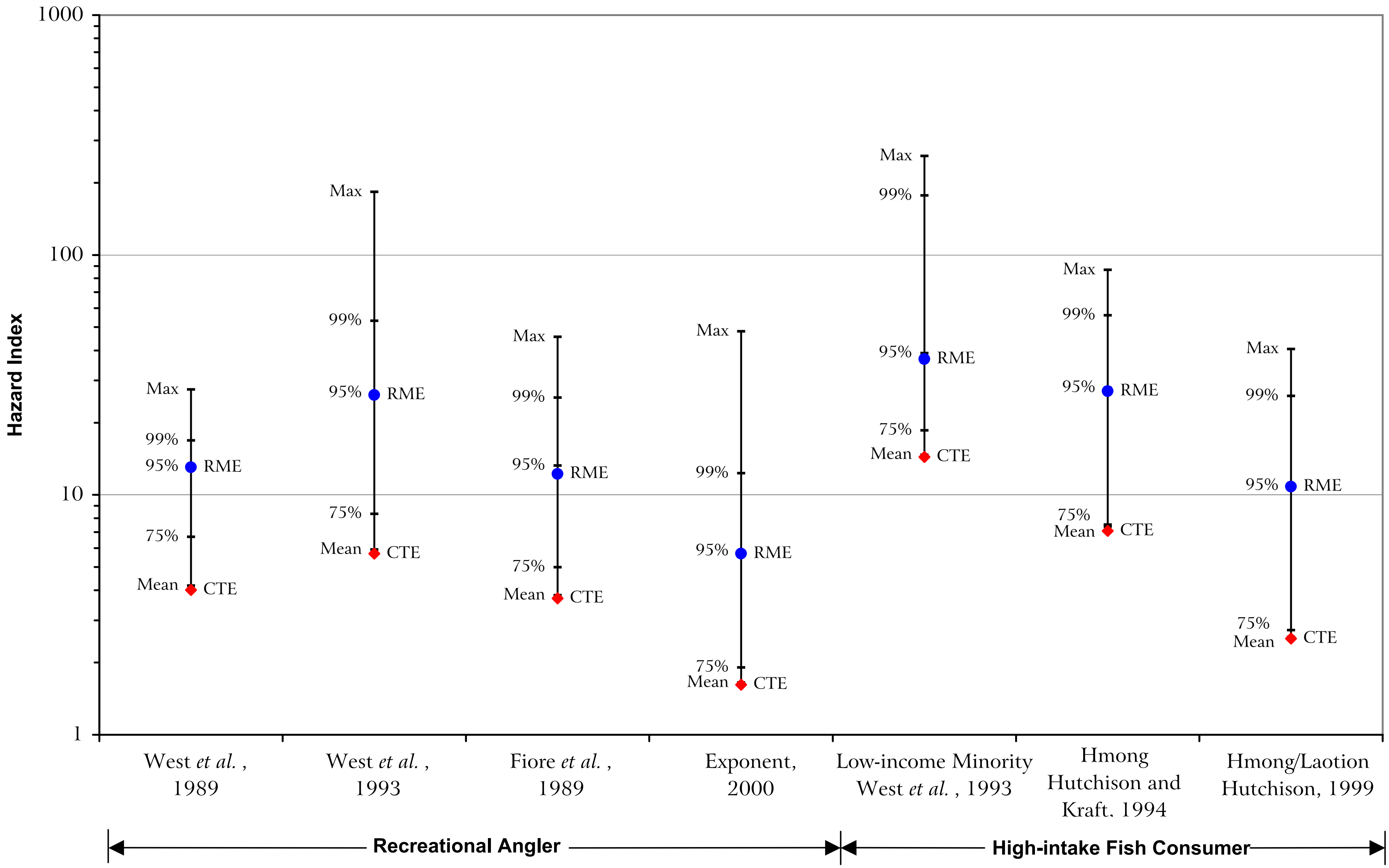


Figure 5-22 Comparison of CTE and RME Risk Values with Distribution Data - De Pere to Green Bay Reach

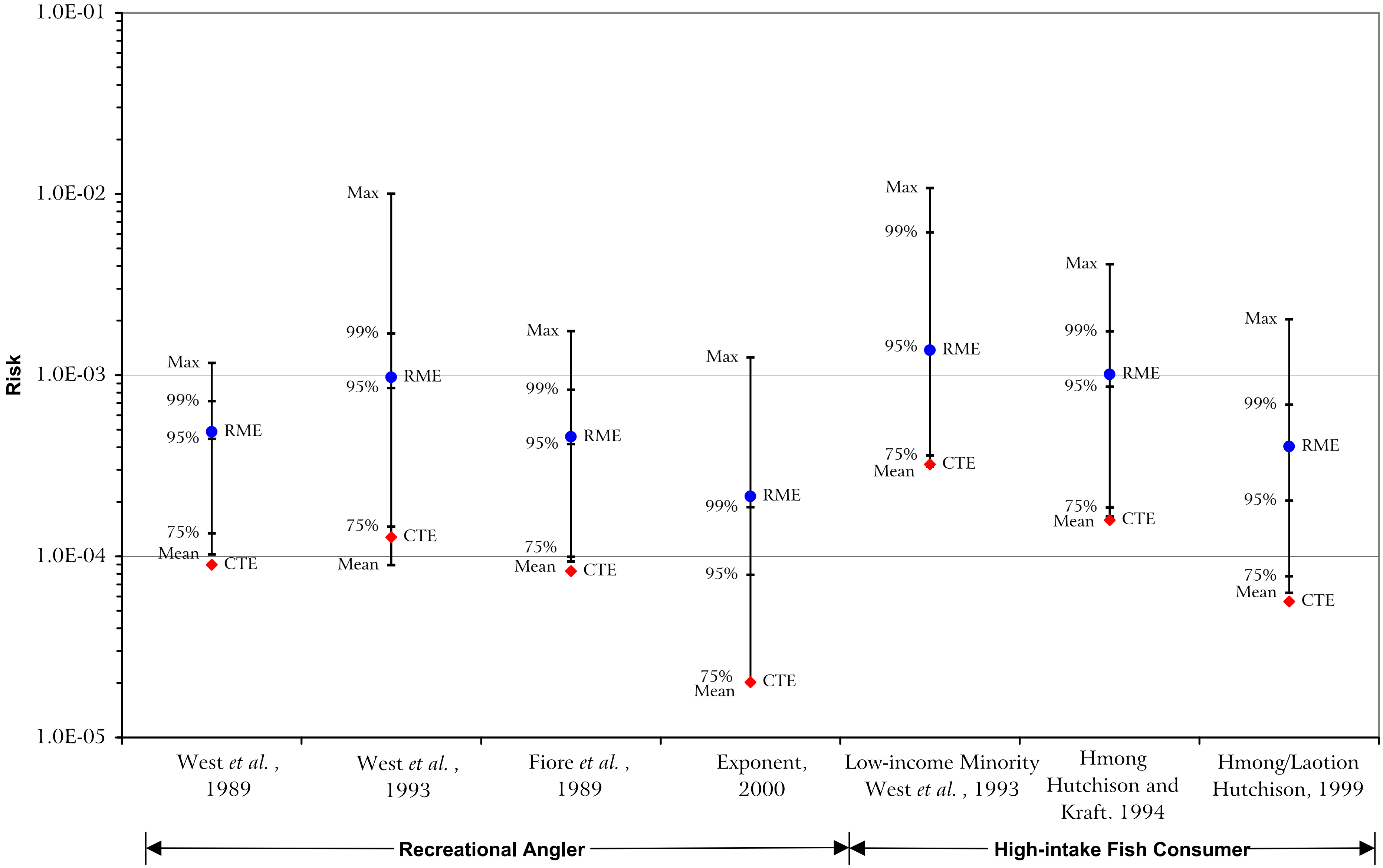


Figure 5-23 Comparison of CTE and RME Hazard Index Values with Distribution Data - De Pere to Green Bay Reach

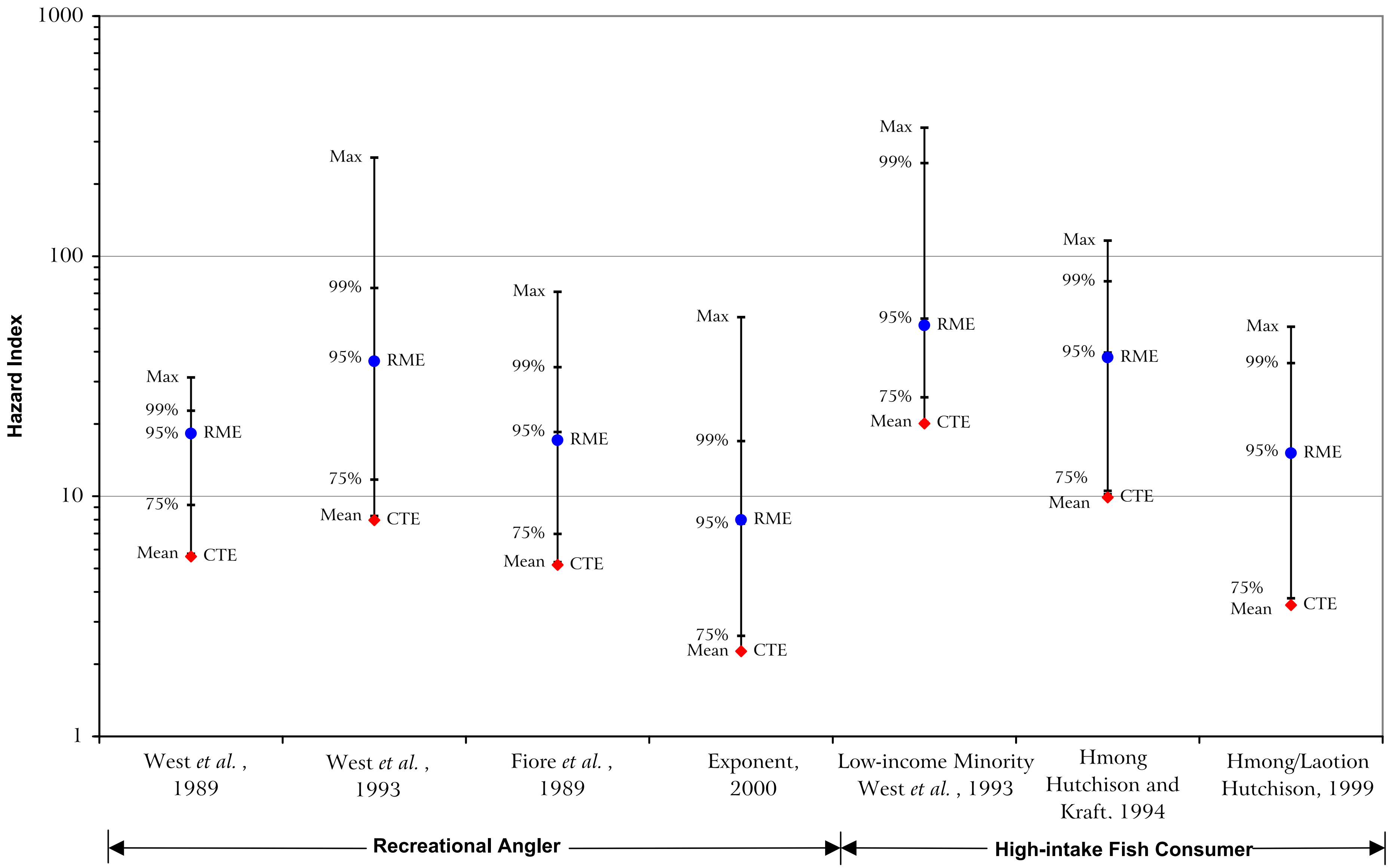


Figure 5-24 Risk Variability Evaluation for Recreational Angler - Little Lake Butte des Morts Reach

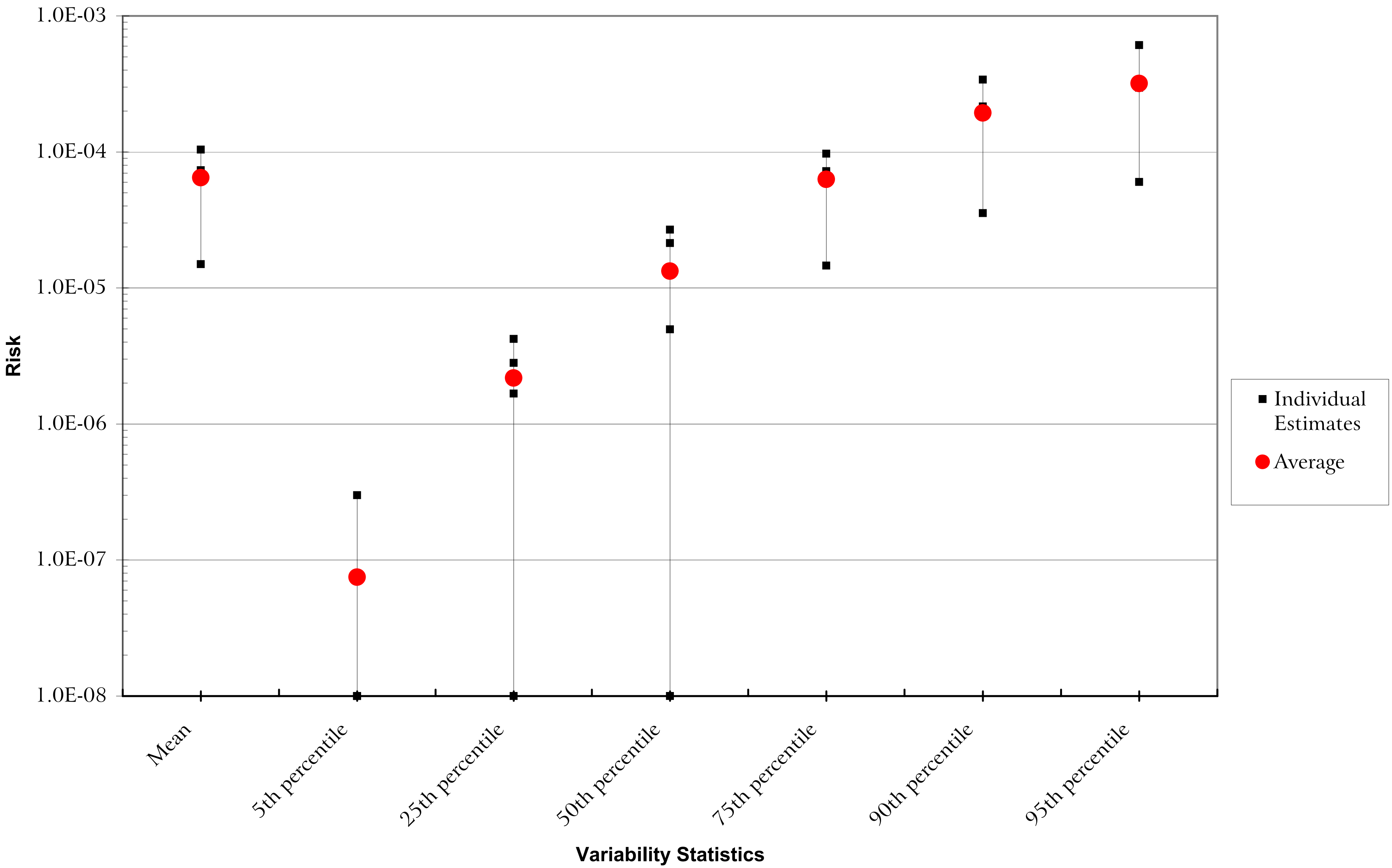


Figure 5-25 Hazard Index Variability Evaluation for Recreational Angler - Little Lake Butte des Morts Reach

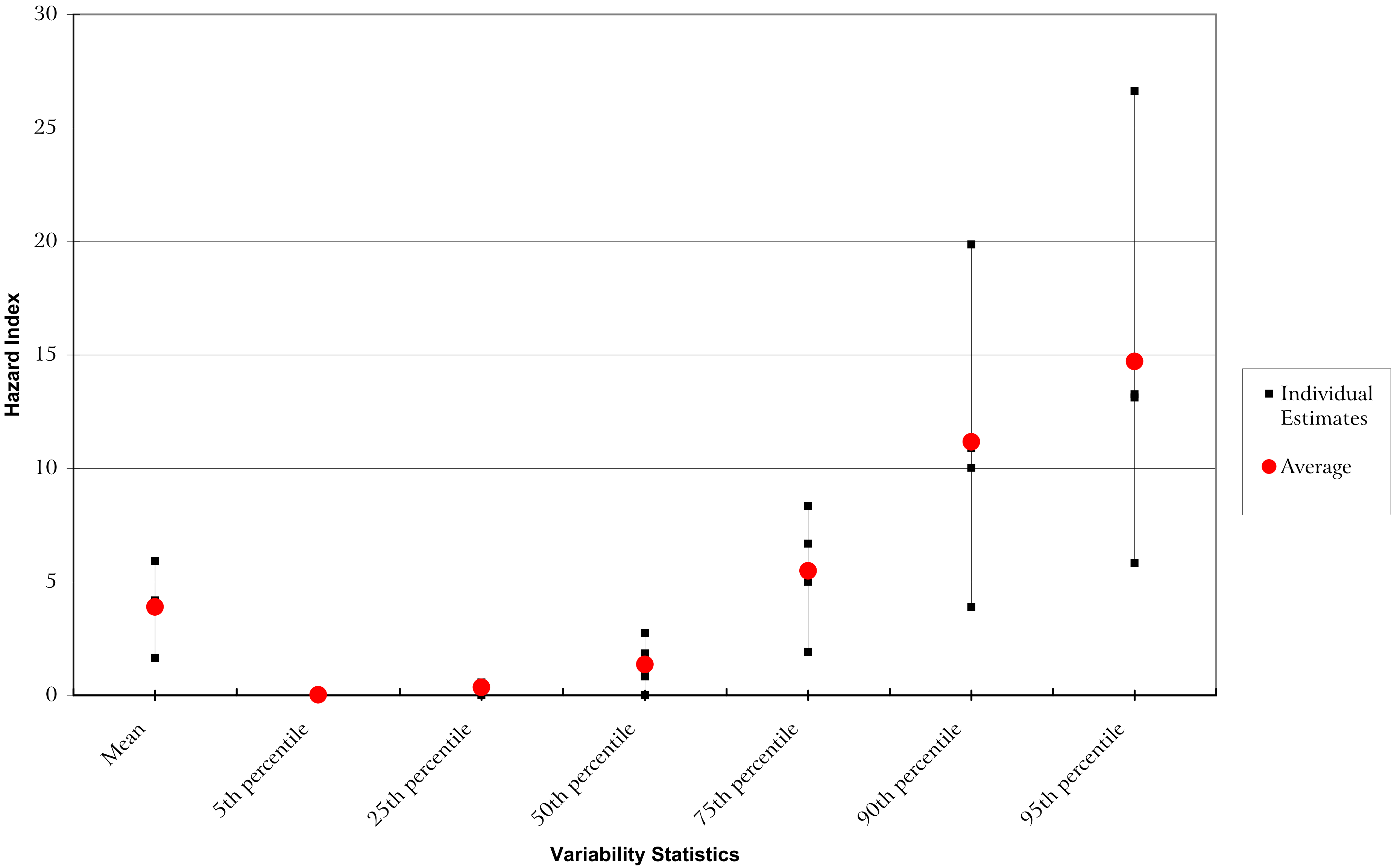


Figure 5-26 Risk Variability Evaluation for Recreational Angler - De Pere to Green Bay Reach

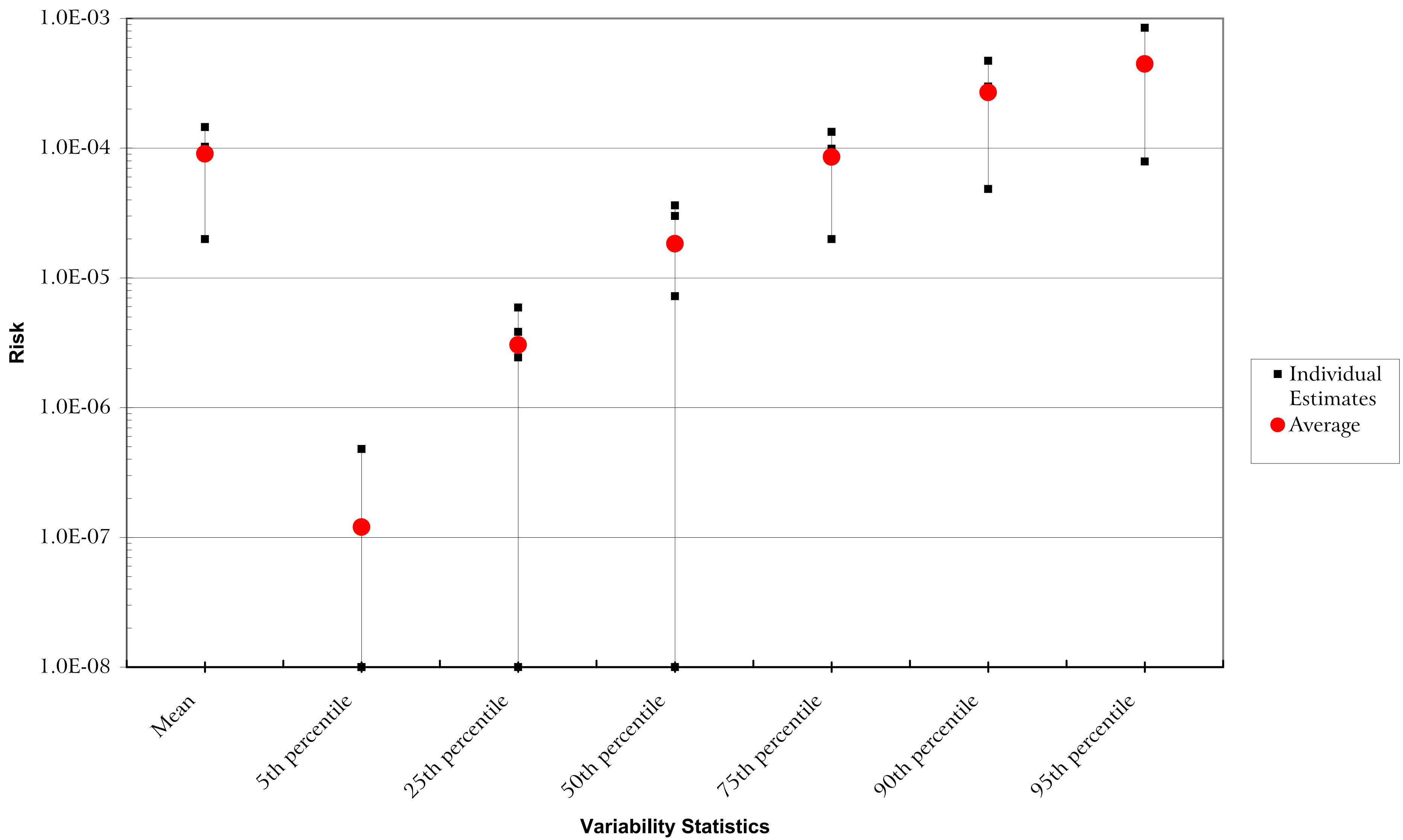


Figure 5-27 Hazard Index Variability Evaluation for Recreational Angler - De Pere to Green Bay Reach

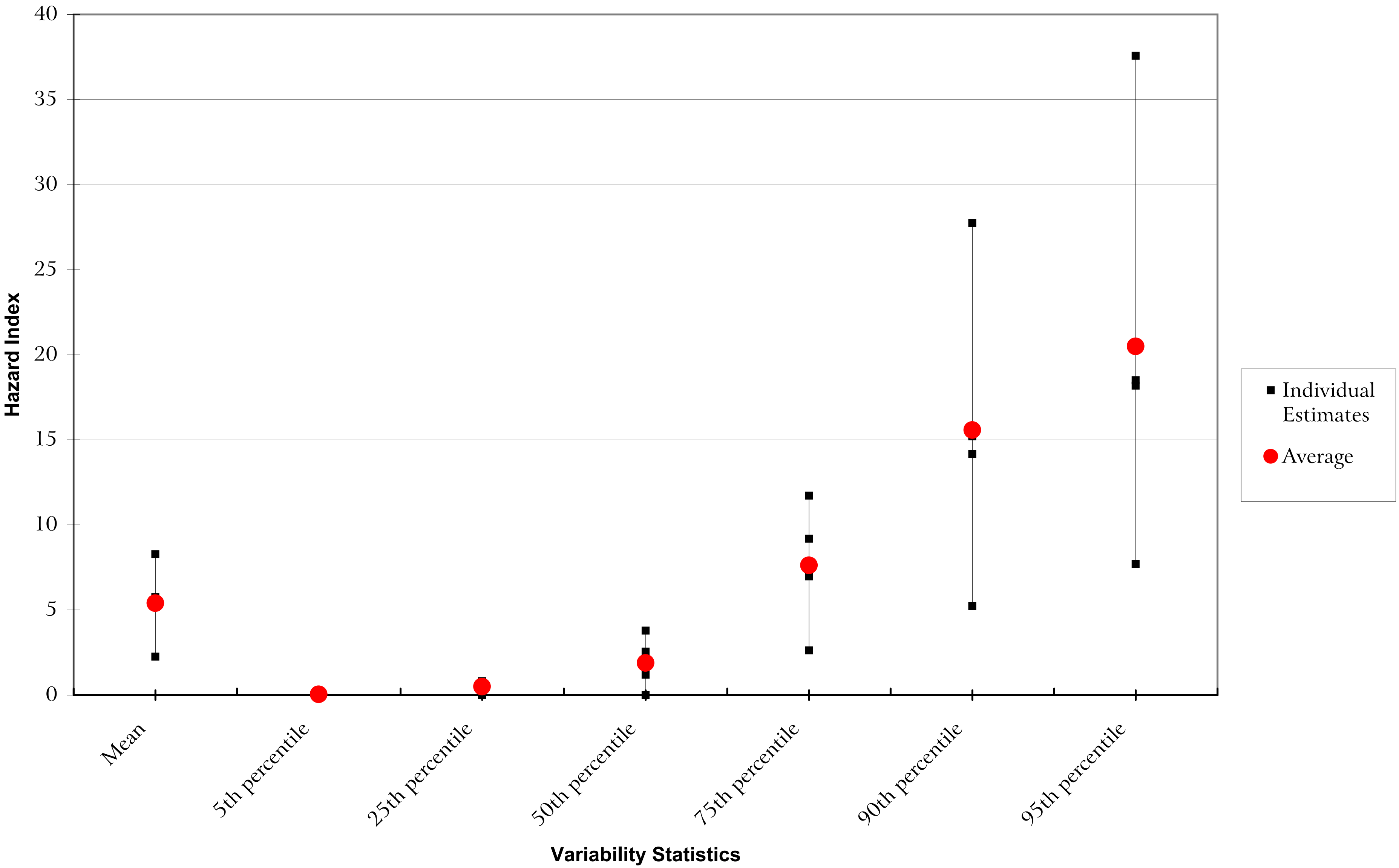


Figure 5-28 Risk Variability Evaluation for High-intake Fish Consumer - Little Lake Butte des Morts Reach

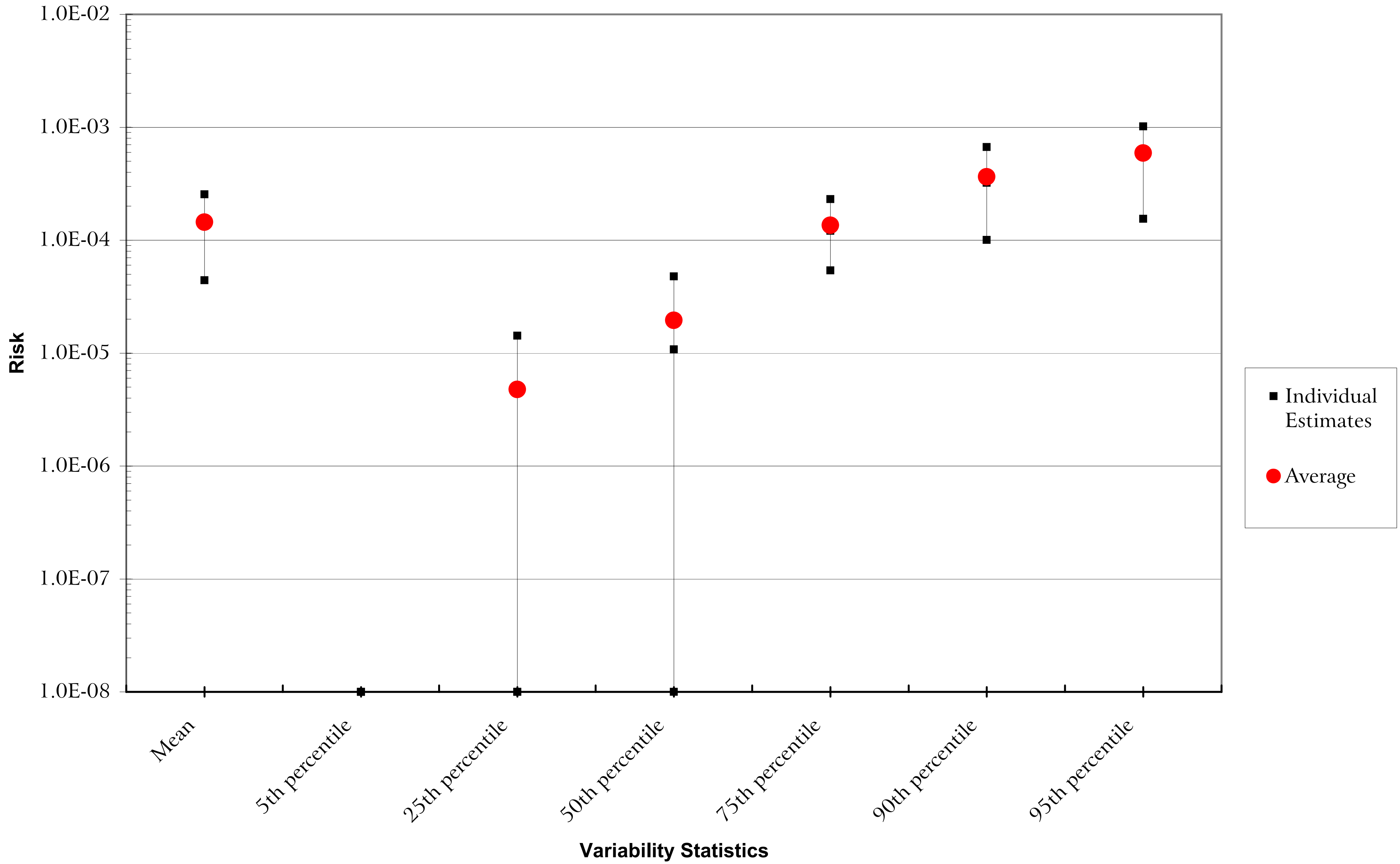


Figure 5-29 Hazard Index Variability Evaluation for High-intake Fish Consumer - Little Lake Butte des Morts Reach

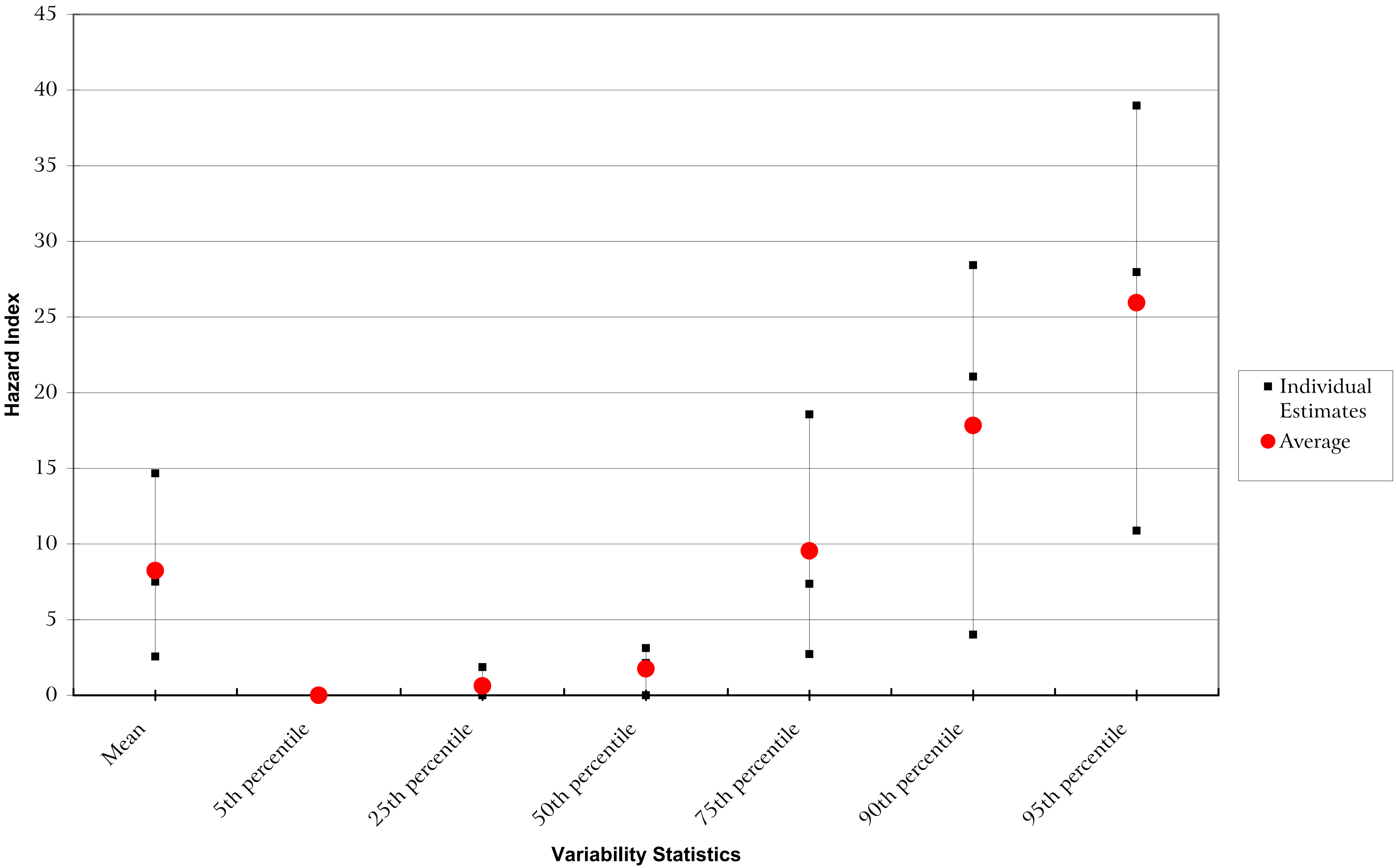


Figure 5-30 Risk Variability Evaluation for High-intake Fish Consumer - De Pere to Green Bay Reach

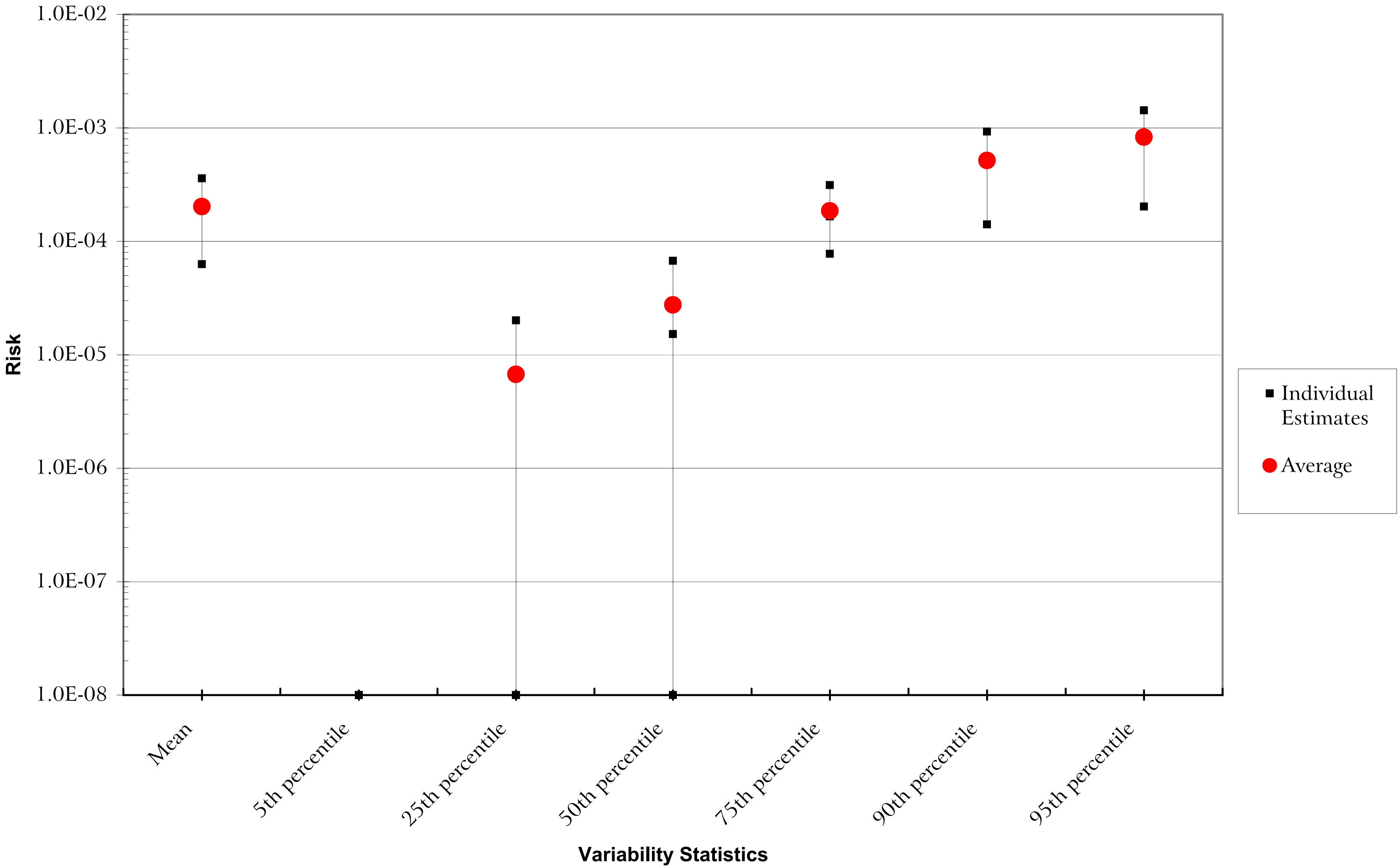


Figure 5-31 Hazard Index Variability Evaluation for High-intake Fish Consumer - De Pere to Green Bay Reach

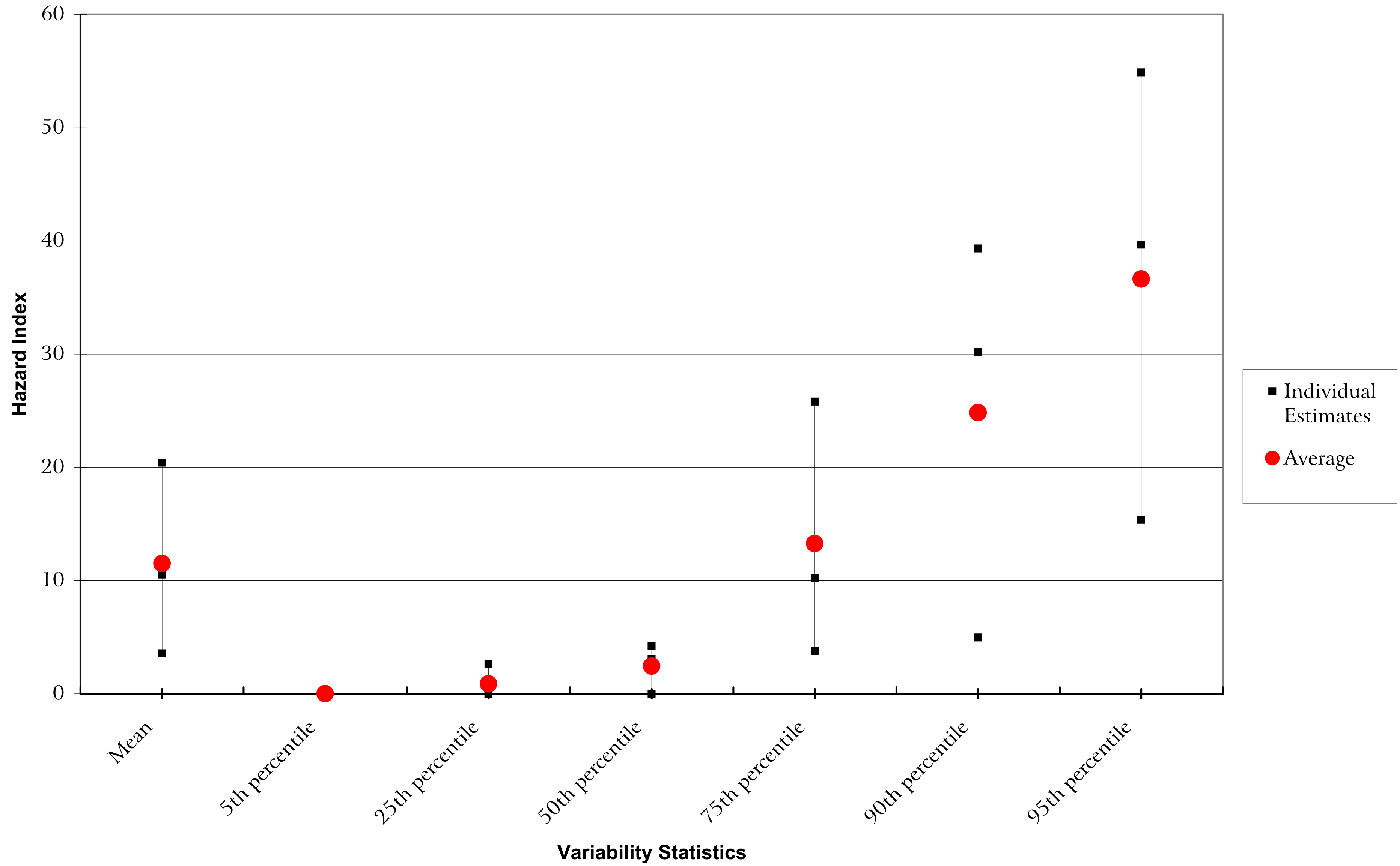
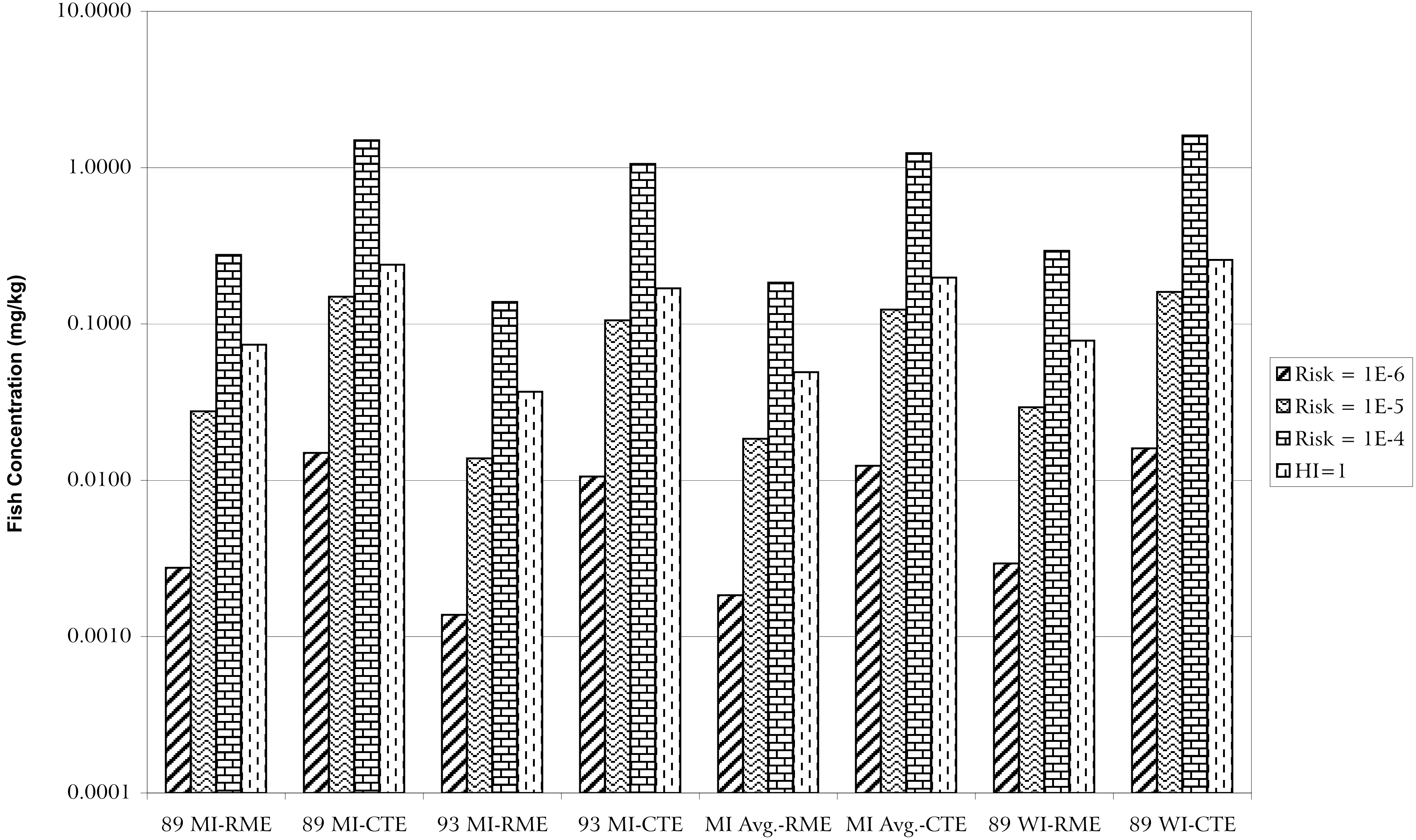


Figure 5-32 Risk-based Fish Concentrations for Recreational Anglers



Key:

89 MI - 1989 Michigan Study

93 MI - 1993 Michigan Study

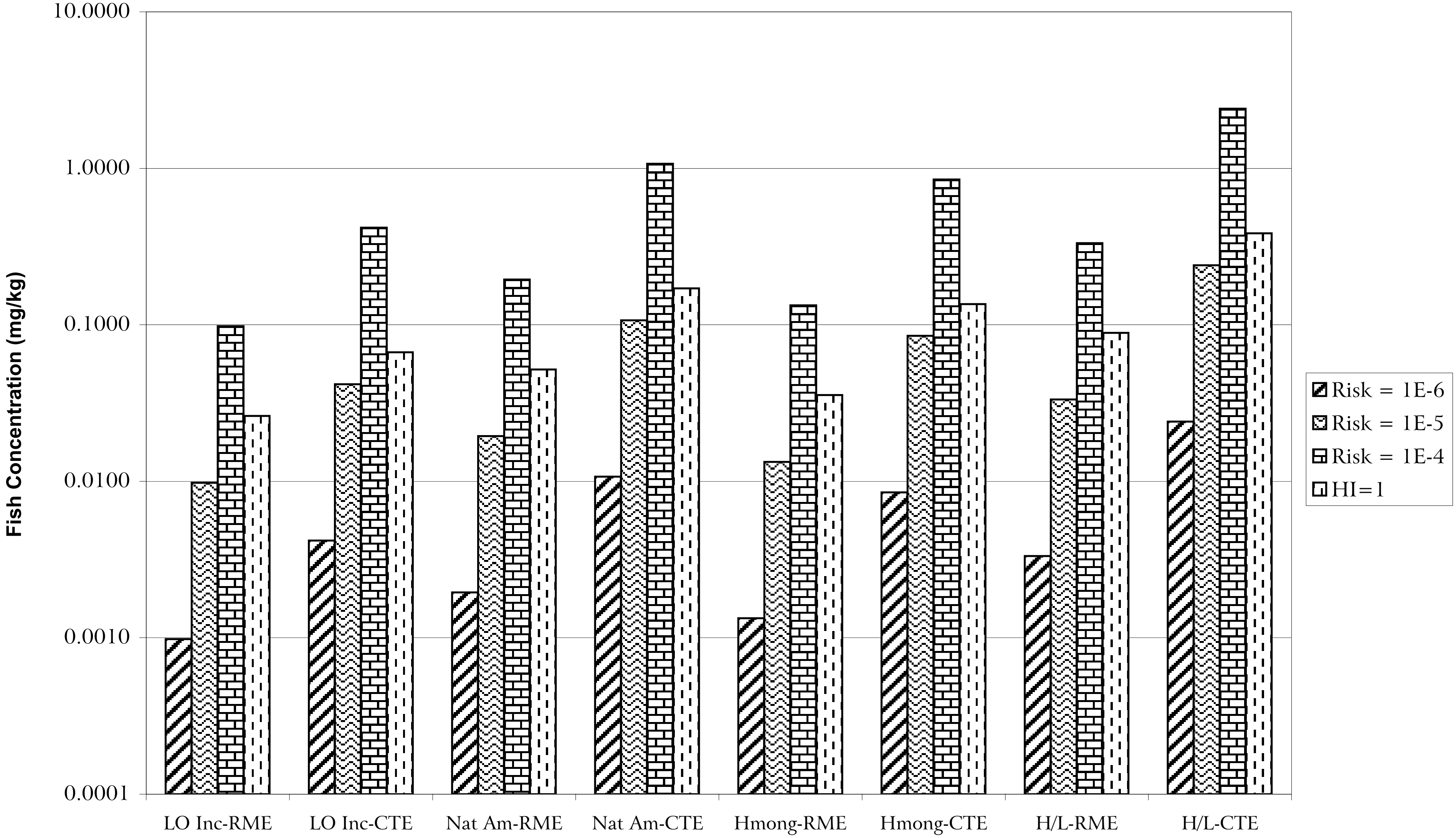
MI Avg. - Uses average intake from 1989 and 1993 Michigan studies.

89 WI - Wisconsin Study

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

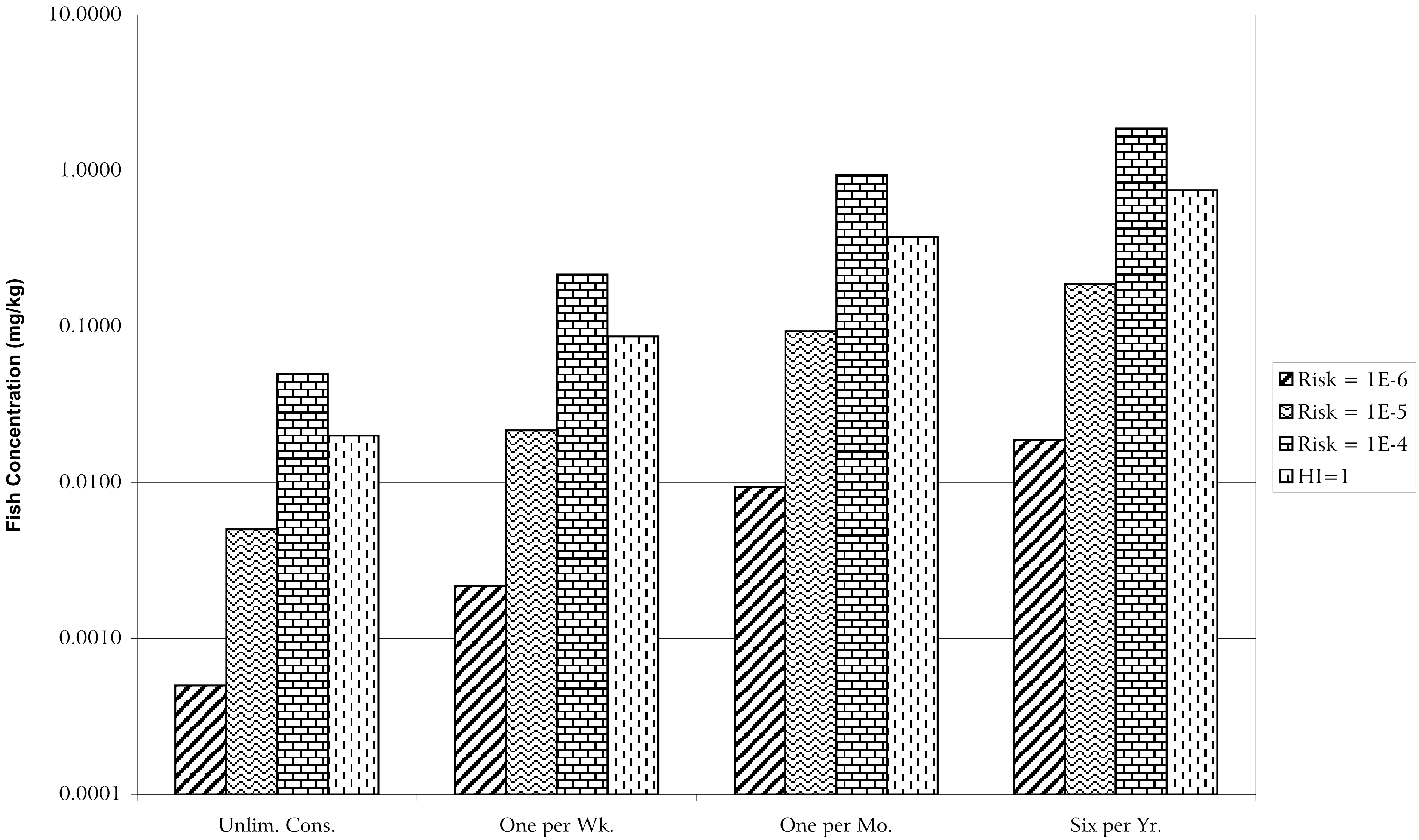
Figure 5-33 Risk-based Fish Concentrations for High-intake Fish Consumers



Key:

CTE - Central Tendency Exposure
LO Inc - Low-income Minotiry Angler
RME - Reasonable Maximum Exposure
H/L - Hmong/Laotian Angler
Nat Am - Native American Angler

Figure 5-34 Risk-based Fish Concentrations Using Assumptions from the Great Lakes Sport Fish Advisory Task Force



Key:

Unlim. Cons. - Unlimited consumption of fish.
One per Wk. - One meal consumed of fish per week.
One per Mo. - One meal consumed of fish per month.
Six per Yr. - Six meals of fish consumed per year.

Table 5-1 Potential Human Receptors and Exposure Pathways for the Lower Fox River and Green Bay

Receptor	Source Medium	Exposure Medium	Exposure Pathway	Comments
Recreational Angler	surface water	outdoor air	inhalation	Pathway potentially complete.
		water	ingestion dermal	Pathways potentially complete, but exposure likely to be intermittent and for short periods.
	surface water and sediment	fish	ingestion	Pathway potentially complete.
High-intake Fish Consumer	surface water	outdoor air	inhalation	Pathway potentially complete.
		water	ingestion dermal	Pathways potentially complete, but exposure likely to be intermittent and for short periods.
	surface water and sediment	fish	ingestion	Pathway potentially complete.
Hunter	surface water	outdoor air	inhalation	Pathway potentially complete.
		water	ingestion dermal	Pathways potentially complete, but exposure likely to be intermittent and for short periods.
	surface water and sediment	waterfowl	ingestion	Pathway potentially complete.
Drinking Water User	surface water	tap water	ingestion dermal	Pathways potentially complete. Water upstream of dam in Appleton and in Green Bay at Marinette is used for drinking. Water is treated before distribution.
		indoor air	inhalation	
Local Resident	surface water	outdoor air	inhalation	Pathway potentially complete.
Recreational Water User	surface water	outdoor air	inhalation	Pathways potentially complete as a result of swimming, wading, water skiing, jet skiing; no beaches in Fox River, beaches in Green Bay.
		water	ingestion dermal	
	sediment	sediment	ingestion dermal	
Marine Construction Worker	surface water	outdoor air	inhalation	Pathways potentially complete.
		water	ingestion dermal	
	sediment	sediment	ingestion dermal	

Table 5-2 Fish Consumption Advisories for Lower Fox River and Green Bay

Water Body/ Fish Species	Eat No More than One Meal/Week or 52 Meals/Year (0.05–0.2 ppm PCBs in fish)	Eat No More than One Meal/Month or 12 Meals/Year (0.2–1.0 ppm PCBs in fish)	Eat No More than One Meal Every 2 Months or 6 Meals/Year (1.0–1.9 ppm PCBs in fish)	Do Not Eat (>1.9 ppm PCBs in fish)
Fox River from Little Lake Butte des Morts to the De Pere Dam				
Walleye		All Sizes		
Northern Pike		All Sizes		
White Bass		All Sizes		
White Perch		All Sizes		
Smallmouth Bass		All Sizes		
Yellow Perch	All Sizes			
Carp				All Sizes
Fox River from the mouth up to the De Pere Dam				
Walleye		Less than 16"	16"–22"	Larger than 22"
Northern Pike		Less than 25"	Larger than 25"	
White Sucker			All Sizes	
White Bass				All Sizes
Black Crappie		Less than 9"	Larger than 9"	
Bluegill		All Sizes		
Rock Bass		All Sizes		
Yellow Perch		All Sizes		
Smallmouth Bass			All Sizes	
Carp				All Sizes
Channel Catfish				All Sizes
Sheepshead		Less than 10"	10"–13"	Larger than 13"

Table 5-2 Fish Consumption Advisories for the Lower Fox River and Green Bay (Continued)

Water Body/ Fish Species	Eat No More than One Meal/Week or 52 Meals/Year (0.05–0.2 ppm PCBs in fish)	Eat No More than One Meal/Month or 12 Meals/Year (0.2–1.0 ppm PCBs in fish)	Eat No More than One Meal Every 2 Months or 6 Meals/Year (1.0–1.9 ppm PCBs in fish)	Do Not Eat (>1.9 ppm PCBs in fish)
Green Bay (south of Marionette and its tributaries, except the Lower Fox River)				
Northern Pike	Less than 22"	Larger than 22"		
Walleye		Less than 17"	17"–26"	Larger than 26"
White Bass				All Sizes
Yellow Perch	All Sizes			
Carp				All Sizes
White Perch			All Sizes	
Smallmouth Bass		All Sizes		
Channel Catfish			All Sizes	
White Sucker		All Sizes		
Rainbow Trout		All Sizes		
Chinook Salmon		Less than 30"	Larger than 30"	
Whitefish			All Sizes	
Splake		Less than 16"	16"–20"	Larger than 20"
Brown Trout		Less than 17"	17"–28"	Larger than 28"
Sturgeon				All Sizes

Table 5-3 Data Summary for 1998 Whole Body Fish Tissue Samples

Constituent	Maximum Detected Concentration (mg/kg)	Average Concentration[1] (mg/kg)	Frequency of Detection
PAHs			
1-Methylnaphthalene	0.027	0.00793	9 / 12
1-Methylphenanthrene	ND	0.004	0 / 12
2,3,5-Trimethylnaphthalene	0.034	0.00683	3 / 12
2,6-Dimethylnaphthalene	0.014	0.0051	3 / 12
2-Methylnaphthalene	0.047	0.01203	10 / 12
Acenaphthene	0.0051	0.00412	2 / 12
Acenaphthylene	ND	0.004	0 / 12
Anthracene	0.0042	0.00402	1 / 12
Benzo(a)anthracene	0.016	0.00583	2 / 12
Benzo(a)pyrene	0.016	0.00583	2 / 12
Benzo(b)fluoranthene	0.016	0.00567	2 / 12
Benzo(e)pyrene	0.0064	0.00438	2 / 12
Benzo(g,h,i)perylene	0.017	0.00617	2 / 12
Benzo(k)fluoranthene	0.02	0.00633	2 / 12
Chrysene	0.018	0.00625	2 / 12
Dibenz(a,h)anthracene	0.017	0.00617	2 / 12
Fluoranthene	0.024	0.00718	5 / 12
Fluorene	0.0064	0.0044	5 / 12
Indeno(1,2,3-cd)pyrene	0.016	0.006	2 / 12
Naphthalene	0.018	0.00788	10 / 12
Perylene	ND	0.004	0 / 12
Phenanthrene	0.01	0.00575	7 / 12
Pyrene	0.022	0.00693	3 / 12
PCBs			
Total PCBs	8.279	2.443	26 / 26
Dioxins			
2,3,7,8-TCDD	0.000002	0.00000076	17 / 17

Notes:

[1] Average concentration includes one-half the detection limit for non-detect samples.

ND - Not Detected.

Table 5-4 Toxicity Criteria and Calculated RBSCs

Constituent	Oral Reference Dose (mg/kg-day)	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Noncancer RBSC (mg/kg)	Cancer RBSC (mg/kg)
PAHs				
1-Methylnaphthalene [1]	0.04	NA	2.0	NA
2,3,5 Trimethylnaphthalene [1]	0.04	NA	2.0	NA
2,6 Dimethylnaphthalene [1]	0.04	NA	2.0	NA
2-Methylnaphthalene	0.04	NA	2.0	NA
Acenaphthene	0.06	NA	3.0	NA
Anthracene	0.3	NA	15	NA
Benzo(a)anthracene	NA	0.73	NA	6.85E-04
Benzo(a)pyrene	NA	7.3	NA	6.85E-05
Benzo(b)fluoranthene	NA	0.73	NA	6.85E-04
Benzo(e)pyrene [2]	0.06	NA	3.0	NA
Benzo(g,h,i)perylene [2]	0.06	NA	3.0	NA
Benzo(k)fluoranthene	NA	0.073	NA	6.85E-03
Chrysene	NA	0.0073	NA	6.85E-02
Dibenz(a,h)anthracene	NA	7.3	NA	6.85E-05
Fluoranthene	0.04	NA	2.0	NA
Fluorene	0.04	NA	2.0	NA
Indeno(1,2,3-cd)pyrene	NA	0.73	NA	6.85E-04
Naphthalene	0.04	NA	2.0	NA
Phenanthrene [3]	0.3	NA	15	NA
Pyrene	0.03	NA	1.5	NA
PCBs				
Total PCBs	2.00E-05	2.0	0.001	2.50E-04
Dioxins				
2,3,7,8-TCDD	NA	150,000	NA	3.33E-09

Notes:

[1] Toxicity criteria for 2-methylnaphthalene were used to evaluate this constituent.
[2] Toxicity criteria for acenaphthene were used to evaluate this constituent.
[3] Toxicity criteria for anthracene were used to evaluate this constituent.
NA - Not available.

Table 5-5 Screening of Constituents Against RBSCs and Calculated Cancer Risks

Constituent	Maximum Detected Concentration (mg/kg)	RBSC for Fish Ingestion (mg/kg)	Does Max. Detect Exceed RBSC?	Calculated Cancer Risk
PAHs				
1-Methylnaphthalene	0.027	2.0	No	
2,3,5 Trimethylnaphthalene	0.034	2.0	No	
2,6 Dimethylnaphthalene	0.014	2.0	No	
2-Methylnaphthalene	0.047	2.0	No	
Acenaphthene	0.0051	3.0	No	
Anthracene	0.0042	15	No	
Benzo(a)anthracene	0.016	6.85E-04	YES	2.3E-05
Benzo(a)pyrene	0.016	6.85E-05	YES	2.3E-04
Benzo(b)fluoranthene	0.016	6.85E-04	YES	2.3E-05
Benzo(e)pyrene	0.0064	3.0	No	
Benzo(g,h,i)perylene	0.017	3.0	No	
Benzo(k)fluoranthene	0.02	6.85E-03	YES	2.9E-06
Chrysene	0.018	6.85E-02	No	
Dibenz(a,h)anthracene	0.017	6.85E-05	YES	2.5E-04
Fluoranthene	0.024	2.0	No	
Fluorene	0.0064	2.0	No	
Indeno(1,2,3-cd)pyrene	0.016	6.85E-04	YES	2.3E-05
Naphthalene	0.018	2.0	No	
Phenanthrene	0.01	15	No	
Pyrene	0.022	1.5	No	
PCBs				
Total PCBs	8.279	0.00025	YES	3.3E-02
Dioxins				
2,3,7,8-TCDD	0.000002	3.33E-09	YES	6.0E-04

Table 5-6 Permeability Coefficients for Chemicals of Potential Concern

Chemical	Kp (cm/hr)	Basis
PCB	0.71	Estimated based on hexachlorobiphenyl
Dioxins/Furans	1.4	Estimated based on 2,3,7,8-TCDD
Dieldrin	0.016	Estimated
DDT	0.43	Estimated
DDE	0.24	Estimated
DDD	0.28	Estimated
Arsenic	0.001	Default value for inorganics
Lead	4×10^{-6}	Measured based on lead acetate
Mercury	1×10^{-3}	Measured based on mercuric chloride

Source:

Dermal Exposure Assessment: Principles and Application (EPA, 1992a).

Table 5-7 Calculated Permeability Coefficients for PCB Aroclors and PCB, Dioxin, and Furan Congeners

Chemical of Potential Concern	Molecular Weight (g/mol)	Log K_{ow}	Estimated Kp (cm/hr)
PCB Aroclors			
Aroclor 1016	257	5.1	2.15E-01
Aroclor 1221	192	4.4	1.71E-01
Aroclor 1232	221	4.85	2.37E-01
Aroclor 1242	261	6.3	2.21E-01
Aroclor 1248	288	6.05	6.59E-01
Aroclor 1254	327	6.45	7.32E-01
Aroclor 1260	372	6.9	8.12E-01
PCB Congeners			
3,3',4,4'-TeCB (PCB-77)	291.99	6.1	6.76E-01
2,3,3',4,4'-PeCB (PCB-105)	326.4	6	3.54E-01
2,3,4,4',5-PeCB (PCB-114)	326.4	6.35	6.27E-01
2,3',4,4',5-PeCB (PCB-118)	326.4	6.35	6.27E-01
2',3,4,4',5-PeCB (PCB-123)	326.4	6.35	6.27E-01
3,3',4,4',5-PeCB (PCB-126)	326.4	6.35	6.27E-01
2,3,3',4,4',5-HxCB (PCB-156)	360.9	7	1.12E+00
2,3,3',4,4',5'-HxCB (PCB-157)	360.9	7	1.12E+00
2,3',4,4',5,5'-HxCB (PCB-167)	360.9	7	1.12E+00
3,3',4,4',5,5'-HxCB (PCB-169)	360.88	7.55	2.75E+00
2,2',3,3',4,4',5-HpCB (PCB-170)	395.32	7.08	7.86E-01
2,2',3,4,4',5,5'-HpCB (PCB-180)	395.32	7.2	9.56E-01
2,3,3',4,4',5,5'-HpCB (PCB-189)	395.3	6.85	5.40E-01
Dioxin Congeners			
1,2,3,7,8-PCDD	356.4	7.4	2.29E+00
1,2,3,4,7,8-HxCDD	391	7.8	2.71E+00
1,2,3,6,7,8-HxCDD	391	7.8	2.71E+00
1,2,3,7,8,9-HxCDD	391	7.8	2.71E+00
1,2,3,4,6,7,8-HpCDD	425.2	8	2.32E+00
OCDD	460	8.2	1.98E+00
Furan Congeners			
2,3,7,8-TCDF	306	6.1	5.55E-01
1,2,3,7,8-PCDF	340.42	6.5	6.58E-01
2,3,4,7,8-PCDF	340.42	6.5	6.58E-01
1,2,3,4,7,8-HxCDF	374.87	7	9.19E-01
1,2,3,6,7,8-HxCDF	374.87	7	9.19E-01
1,2,3,7,8,9-HxCDF	374.87	7	9.19E-01
2,3,4,6,7,8-HxCDF	374.87	7	9.19E-01
1,2,3,4,6,7,8-HpCDF	409.31	7.4	1.09E+00
1,2,3,4,7,8,9-HpCDF	409.31	6.9	4.81E-01
OCDF	443.8	8	1.79E+00

Sources:

Mackay *et al.* (1992a, 1992b) for molecular weight and Log K_{ow}. Kp estimated using equation in *Dermal Exposure Assessment: Principles and Application* (EPA, 1992a).

Table 5-8 Absorption Factors for Chemicals for Ingestion of Sediment

Chemical	Absorption Factor (percent/event)
PCB	100%
Dioxins/Furans	100%
Dieldrin	100%
DDT	100%
DDE	100%
DDD	100%
Arsenic	32%
Lead	100%
Mercury	100%

Source:

Professional judgement except for arsenic, which is based on Freeman *et al.* (1993).

Table 5-9 Absorption Factors for Chemicals for Dermal Contact with Sediment

Chemical	Absorption Factor (percent/event)
PCB	6%
Dioxins/Furans	3%
Dieldrin	10%
DDT	10%
DDE	10%
DDD	10%
Arsenic	3.2%
Lead	1.0%
Mercury	1.0%

Source:
Assessing Dermal Exposure from Soil (EPA, 1995a).

Table 5-10 Fish Ingestion Assumptions for Recreational Angler

Intake Parameter	Recreational Angler RME (West *et al.*, 1989)	Recreational Angler CTE (West *et al.*, 1989)	Recreational Angler RME (West *et al.*, 1993)	Recreational Angler CTE (West *et al.*, 1993)	Recreational Angler RME (Fiore *et al.*, 1989)	Recreational Angler CTE (Fiore *et al.*, 1989)
IR (g/day or g/meal)	39	12	78	17	227	227
EF (days/year or meals/year)	365	365	365	365	59	18
Comparison of Fish Intake Assumptions						
Basis: Annualized IR						
IR (g/day)	39	12	78	17	37	11
EF (days/year)	365	365	365	365	365	365
Basis: Normalized Meals per Year						
IR (g/meal)	227	227	227	227	227	227
EF (meals/year)	63	19	125	27	59	18

Key:

IR is daily consumption of fish (g/day or g/meal).

EF is exposure frequency or number of days per year when sport-caught fish is eaten (days/year), or the number of meals consumed per year (meals/year).

Table 5-11 Fish Ingestion Assumptions for High-intake Fish Consumer

Intake Parameter	Low-income, Minority Angler (West *et al.*, 1993) RME	CTE	Native American Angler (Peterson *et al.*, 1994; Fiore *et al.*, 1989) RME	CTE	Hmong Angler (Hutchison and Kraft, 1994) RME	CTE	Hmong/Laotian Angler (Hutchison, 1999) RME	CTE
IR	110	43	227	227	227	227	227	227
EF	365	365	89	27	130	34	52	12
Comparison of Fish Intake Assumptions								
Basis: Annualized IR								
IR (g/day)	110	43	55	17	81	21	32	8
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	177	69	89	27	130	34	52	12

Key:

IR is daily consumption of fish (g/day or g/meal).

EF is exposure frequency or number of days per year when sport-caught fish is eaten (days/year), or the number of meals consumed per year (meals/year).

Table 5-12 Consumption of Sport Fish by Hmong Anglers

Fish Consumption	Meals/Year	Fraction of Anglers
Never	0	0.08
Once per month	12	0.53
2–3 times per month	30	0.15
Once per week	52	0.09
2–3 times per week	130	0.14
Every day	365	0
Average	34 meals/year	
95th Percentile	130 meals/year	

Source:
Hutchison and Kraft, 1994.

Table 5-13 Consumption of Fish from De Pere to Green Bay Reach of Lower Fox River by Hmong/Laotian Anglers

Fish Consumption	Meals/Year	Fraction of Anglers
Never	0	0.394
Once per month	12	0.515
Once per week	52	0.076
2–3 times per week	130	0.015
Average	12 meals/year	
95th Percentile	52 meals/year	

Source:
Hutchison, 1999.

Table 5-14 Average Size of Meal Consumed by Hmong

Most Likely Meal Size	Bass	Carp	Trout	Salmon	Total	Fraction of Weighed Estimates
1/3 pound	3	2	1	1	7	0.39
1/2 pound	2	4	1	1	8	0.44
1 pound	2	0	1	0	3	0.17
Other	8	3	2	2	15	

Note:
Average quantity: 0.52 lbs.
Source:
Hutchison, 1994 (Sheboygan Study).

Table 5-15 Summary of Intake Parameter Values for Recreational Anglers—RME Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	50 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 50 days	based on exposure period [b]
Fish Intake			
Basis: Annualized Ingestion Rate			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	59 g/day	average of 95th percentiles for [c] and [d]
Basis: Normalized Meals per Year			
EF (exposure frequency)	=	94 meals/yr	average of 95th percentiles for [c] and [d]
IR (meal size)	=	227 g/meal	assumed meal size
Other Fish Intake Assumptions			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	95 days/yr	based on the number of meals per year
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	95 days/yr	based on the number of meals per year
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	95 days/yr	based on the number of meals per year
ET (exposure time)	=	6 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .
[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .
[c] West *et al.* , 1989.
[d] West *et al.* , 1993.

Table 5-16 Summary of Intake Parameter Values for Recreational Anglers—CTE Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	30 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
Ingestion of Fish:			
<u>Basis: Annualized Ingestion Rate</u>			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	15 g/day	average of mean values for [c] and [d]
<u>Basis: Normalized Meals per Year</u>			
EF (exposure frequency)	=	23 meals/yr	average of mean values for [c] and [d]
IR (meal size)	=	227 g/meal	assumed meal size
<u>Other Fish Intake Assumptions</u>			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	24 days/yr	based on the number of meals per year
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	24 days/yr	based on the number of meals per year
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	18,150 cm^2	average mean value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	935 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	24 days/yr	based on the number of meals per year
ET (exposure time)	=	6 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .
[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .
[c] West *et al.* , 1989.
[d] West *et al.* , 1993.

Table 5-17 Summary of Intake Parameter Values for High-intake Fish Consumers—RME Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	50 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 50 days	based on exposure period [b]
Ingestion of Fish:			
<u>Basis: Annualized Ingestion Rate</u>			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	81 g/day	95^{th} percentile for [c]
<u>Basis: Normalized Meals per Year</u>			
EF (exposure frequency)	=	130 meals/yr	95^{th} percentile for [c]
IR (fish ingestion rate)	=	227 g/day	assumed meal size
<u>Other Fish Intake Assumptions</u>			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	130 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	130 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	130 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	4 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Hutchison and Kraft, 1994.

Table 5-18 Summary of Intake Parameter Values for High-intake Fish Consumers—CTE Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	30 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
Ingestion of Fish:			
Basis: Annualized Ingestion Rate			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	21 g/day	mean value in [c]
Basis: Normalized Meals per Year			
EF (exposure frequency)	=	34 meals/yr	mean value in [c]
IR (fish ingestion rate)	=	227 g/day	assumed meal size
Other Fish Intake Assumptions			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	34 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	34 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	18,150 cm^2	average mean value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	935 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	34 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	4 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Hutchison and Kraft, 1994.

Table 5-19 Summary of Intake Parameter Values for Hunters—RME Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	50 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 50 days	based on exposure period [b]
Ingestion of Waterfowl:			
EF (exposure frequency)	=	12 meals/yr	based on data from Amundson study [c]
IR (waterfowl ingestion rate)	=	110 g/meal	reasonable maximum meal size presented in [d]
RF (reduction factor)	=	100%	based on data from Amundson study [c]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	12 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	12 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	12 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	8 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Amundson, 1984. Organochlorine pesticides and PCBs in edible tissues of giant Canada geese from the Chicago area.

[d] Pao *et al.* , 1982.

Table 5-20 Summary of Intake Parameter Values for Hunters—CTE Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	30 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
Ingestion of Waterfowl:			
EF (exposure frequency)	=	6 meals/yr	based on data from Amundson study [c]
IR (waterfowl ingestion rate)	=	110 g/meal	reasonable maximum meal size presented in [d]
RF (reduction factor)	=	100%	based on data from Amundson study [c]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	6 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	6 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	18,150 cm^2	average mean value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	935 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	6 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	8 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Amundson, 1984. Organochlorine pesticides and PCBs in edible tissues of giant Canada geese from the Chicago area.

[d] Pao *et al.* , 1982

Table 5-21 Summary of Intake Parameter Values for Drinking Water Users

Assumptions			Comments and References
General Assumptions:			
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
EF (exposure frequency)	=	350 days/year	default for a residential receptor [c]
Young Child (1 to 6 years)			
ED (exposure duration)	=	6 years	value for ages 1–6 [c]
BW (body weight)	=	16.6 kg	average body weight for boys and girls age 1–6 [a]
Ingestion of Water:			
IR (incidental ingestion rate)	=	1.5 L/day	upper-percentile for a child age 3–5 [a]
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Water:			
FBE (fraction of body exposed)	=	100%	whole body while bathing
TBS (total body surface area)	=	8,105 cm^2	average value for a young child [a]
SA (exposed skin area = TBS * FBE)	=	8,105 cm^2	SA = TBS * FBE
ET (exposure time)	=	0.33 hr/day	average time spent in bath [a]
FC (fraction of dermal exposure from site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Water:			
IR (inhalation rate)	=	1.0 m^3/hr	value for child engaged in light activities [a]
ET (exposure time)	=	0.33 hr/day	average time spent in bath [a]
ABS (absorption factor)	=	100%	conservatively assumed
Older Child to Adult (7 to 31 years)			
ED (exposure duration)	=	24 years	value for ages 7–31 [c]
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
Ingestion of Water:			
IR (incidental ingestion rate)	=	2.3 L/day	upper-percentile for an adult [a]
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Water:			
FBE (fraction of body exposed)	=	100%	whole body while bathing/showering
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
SA (exposed skin area = TBS * FBE)	=	21,850 cm^2	SA = TBS * FBE
ET (exposure time)	=	0.25 hr/day	average time spent in bath/shower [a]
FC (fraction of dermal exposure from site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Water:			
IR (inhalation rate)	=	1.0 m^3/hr	value for adult engaged in light activities [a]
ET (exposure time)	=	0.25 hr/day	average time spent in bath/shower [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .
[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .
[c] EPA, 1991. *Standard Default Exposure Factors* .

Table 5-22 Summary of Intake Parameter Values for Local Residents

Assumptions			Comments and References
General Assumptions:			
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
EF (exposure frequency)	=	350 days/year	default for a residential receptor [c]
Young Child (1 to 6 years)			
Inhalation of Volatiles from Surface Water:			
ED (exposure duration)	=	6 years	value for ages 1–6 [c]
BW (body weight)	=	16.6 kg	average body weight for boys and girls age 1–6 [a]
IR (inhalation rate)	=	0.42 m^3/hr	daily IR of 10 m^3/day for child 6–8 yrs divided by ET
ET (exposure time)	=	24 hrs/day	total hours in a day
ABS (absorption factor)	=	100%	conservatively assumed
Older Child to Adult (7 to 31 years)			
Inhalation of Volatiles from Surface Water:			
ED (exposure duration)	=	24 years	value for ages 7–31 [b]
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
IR (inhalation rate)	=	0.55 m^3/hr	daily IR of 13.3 m^3/day for adult divided by ET
ET (exposure time)	=	24 hrs/day	total hours in a day
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] EPA, 1991. *Standard Default Exposure Factors* .

Table 5-23 Summary of Intake Parameter Values for Swimmers

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	18 days/yr	1 time per week for 4 warmest months of the year
ED (exposure duration)	=	30 years	default exposure duration for a resident [b]
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [c]
Incidental Ingestion of Surface Water:			
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
ET (exposure time)	=	1 hour/day	average time for swimming per event [a]
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	100.0%	entire body exposed while swimming
SA (exposed skin area = TBS * FBE)	=	21,850 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
ET (exposure time)	=	1 hour/day	average time for swimming per event [a]
IR (inhalation rate)	=	3.2 m^3/hr	value for adults, heavy activity [a]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Sediments:			
IR (incidental ingestion rate)	=	5 mg/day	one-tenth daily soil rate for an adult (see text)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediments:			
FBE (fraction of body exposed)	=	6.75%	corresponds to feet of an adult [a]
SA (exposed skin area = TBS * FBE)	=	1,475 cm^2	SA = TBS * FBE
AF (soil adherence factor)	=	1.0 mg/cm^2	upper value for soil contact [d]
FC (fraction of daily contact occurring at the site)	=	5%	professional judgement (see text)
ABS (skin absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediment Pore Water:			
ET (exposure time)	=	0.25 hour/day	exposure might occur for 15 minutes
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	6.75%	corresponds to feet of an adult [a]
SA (exposed skin area = TBS * FBE)	=	1,475 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook*.
[b] EPA, 1991. *Standard Default Exposure Factors*.
[c] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)*.

[d] EPA, 1992a. *Dermal Exposure Assessment: Principles and Applications*.

Table 5-24 Summary of Intake Parameter Values for Waders

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	51 kg	average body weight of an older child, age 9–18 [a]
EF (exposure frequency)	=	18 days/yr	1 time per week for 4 warmest months of the year
ED (exposure duration)	=	10 years	duration of time from age 9 to age 18
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 10 days	based on exposure period [b]
Incidental Ingestion of Surface Water:			
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction of time ingestion occurs)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
ET (exposure time)	=	0.5 hour/day	assumed time spent wading
TBS (total body surface area)	=	14,400 cm^2	average 50^{th} percentile value for children age 9–18 [a]
FBE (fraction of body exposed)	=	22.9%	feet and lower legs exposed while wading
SA (exposed skin area = TBS * FBE)	=	3,298 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
ET (exposure time)	=	0.5 hour/day	assumed time spent wading
IR (inhalation rate)	=	1.2 m^3/hr	value for children, moderate activity [a]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Sediments:			
IR (incidental ingestion rate)	=	5 mg/day	one-tenth daily soil rate for an older child (see text)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Sediments:			
FBE (fraction of body exposed)	=	7.37%	corresponds to feet of an older child [a]
SA (exposed skin area = TBS * FBE)	=	1,061 cm^2	SA = TBS * FBE
AF (soil adherence factor)	=	1.0 mg/cm^2	upper value for soil contact [c]
FC (fraction of daily contact occurring at the site)	=	10%	professional judgement (see text)
ABS (skin absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediment Pore Water:			
ET (exposure time)	=	0.5 hour/day	exposure might occur for 30 minutes
TBS (total body surface area)	=	14,400 cm^2	average 50^{th} percentile value for children age 9–18 [a]
FBE (fraction of body exposed)	=	7.37%	corresponds to feet of an older child [a]
SA (exposed skin area = TBS * FBE)	=	1,061 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] EPA, 1992a. *Dermal Exposure Assessment: Principles and Applications* .

Table 5-25 Summary of Intake Parameter Values for Marine Construction Workers

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	24 days/yr	twice per month (professional judgement)
ED (exposure duration)	=	25 years	value specified for workers [b]
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 25 days	based on exposure period [c]
Incidental Ingestion of Surface Water:			
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
ET (exposure time)	=	0.5 hrs/day	exposure might occur for one-half hour during the workday
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	11.6%	corresponds to hands and forearms of adult [a]
SA (exposed skin area = TBS * FBE)	=	2,535 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
ET (exposure time)	=	8 hrs/day	hours in a work day
IR (inhalation rate)	=	1.5 m^3/hr	value for outdoor worker, moderate activity [a]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Sediments:			
IR (incidental ingestion rate)	=	25 mg/day	half the daily soil rate for an adult (see text)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediments:			
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of an adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
AF (soil adherence factor)	=	1.0 mg/cm^2	upper value for soil contact [c]
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
ABS (skin absorption factor)	=	varies	chemical-specific (see text)

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .
[b] EPA, 1991. *Standard Default Exposure Factors* .
[c] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .
[d] EPA, 1992a. *Dermal Exposure Assessment: Principles and Applications* .

Table 5-26 Upper-bound Measured Concentrations for the Little Lake Butte des Morts Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	3.6	0.66	ND	1.530E-05	3.749
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	1.32		ND	1.900E-05	21.1
Aroclor 1248	0.156		ND	ND	3.43
Aroclor 1254	1.01		ND	ND	2.93
Aroclor 1260	0.216		ND	ND	1.400
Total PCB Aroclors (less 1016/1254)	2.59	0.66	0	1.530E-05	0.819
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.0031			2.390E-07	0.0264
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.013				0.0106
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					0.0106
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.052			8.380E-08	0.596
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.0057				0.0012
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	ND				3.2E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.0029				0.00743
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	0.00079				0.0025
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					0.00471
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	ND				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.0034				0.0103
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.023			3.230E-08	0.228
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					8.5E-04
Total PCB Congeners (less dioxin-like)	3.49611	0.66	0	1.494E-05	2.85009
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	ND				4.31E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	0.0000018				7.129E-05
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	0.0143			0.0059
4,4'-DDD	ND	ND			0.019
4,4'-DDE	0.0769	0.68			ND
4,4'-DDT	ND	ND			0.050
Inorganics					
Arsenic	ND	ND			5.09
Lead	ND	ND	1.45E-03	1.17E-04	522
Mercury (total)	0.133	ND	7.14E-03	ND	1.45
Mercury (inorganic)					
Mercury (organic)					

Table 5-27 Upper-bound Measured Concentrations for the Appleton to Little Rapids Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	5.06	0.774	ND	9.450E-06	1.479
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.512		ND	8.060E-06	8.89
Aroclor 1248	ND		ND	ND	ND
Aroclor 1254	0.555		ND	ND	0.340
Aroclor 1260	0.155		ND	ND	2.07
Total PCB Aroclors (less 1016/1254)	4.505	0.774	0	9.450E-06	1.139
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.925E-07	0.035
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.138
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					3.5E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				1.31E-07	0.181
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)				3.200E-08	ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					5.2E-05
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					0.0015
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					2.0E-04
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				ND	0.0021
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				ND	0.0061
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				5.000E-08	0.0716
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					1.3E-04
Total PCB Congeners (less dioxin-like)				9.045E-06	1.043
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)			ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	ND	ND		ND
4,4'-DDD	ND	ND	ND		0.0017
4,4'-DDE	0.070	0.121	ND		ND
4,4'-DDT	ND	ND	ND		0.0034
Inorganics					
Arsenic			ND		6.4
Lead			0.0018		88.9
Mercury (total)	0.381	0.0415	9.0E-05	9.000E-05	1.740
Mercury (inorganic)					
Mercury (organic)					

Table 5-28 Upper-bound Measured Concentrations for the Little Rapids to De Pere Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	0.751	1.23		1.230E-05	2.112
Aroclor 1016	ND			ND	ND
Aroclor 1221	ND			ND	ND
Aroclor 1232	ND			ND	ND
Aroclor 1242	0.517			1.420E-05	11.3
Aroclor 1248	0.653			ND	ND
Aroclor 1254	0.563			ND	0.806
Aroclor 1260	0.204			ND	0.266
Total PCB Aroclors (less 1016/1254)	0.188	1.23		1.230E-05	1.306
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.610E-07	0.0579
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0214
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					0.00647
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				6.990E-08	0.584
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					0.0059
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					0.00079
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					0.00569
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					0.0016
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					0.0029
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)					0.0106
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				4.730E-08	0.0223
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					0.00074
Total PCB Congeners (less dioxin-like)				1.202E-05	1.39171
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					6.820E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)					1.170E-04
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND				ND
4,4'-DDD	0.0104				0.0028
4,4'-DDE	0.0744				0.022
4,4'-DDT	ND				0.020
Inorganics					
Arsenic					5.11
Lead			7.07E-04	1.24E-04	274
Mercury (total)	0.287		7.12E-03	2.52E-03	4.04
Mercury (inorganic)					
Mercury (organic)					

Table 5-29 Upper-bound Measured Concentrations for the De Pere to Green Bay Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.76	0.8		1.770E-05	2.984
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.783		ND	1.400E-05	5.72
Aroclor 1248	0.367		ND	ND	ND
Aroclor 1254	0.931		ND	ND	0.630
Aroclor 1260	0.258		ND	ND	0.400
Total PCB Aroclors (less 1016/1254)	1.829	0.8	0	1.770E-05	2.354
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.0038			1.740E-07	0.027
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.0217				0.0106
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)	0.00423			2.170E-08	0.00438
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.0546			5.500E-08	0.0241
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.0059			3.820E-08	9.34E-04
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	0.0012				2.7E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.0064			7.110E-09	0.00199
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	0.0025			1.0E-09	8.0E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)	0.0068			3.030E-09	9.1E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	0.0006				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.0355			2.120E-08	0.00235
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.0246			2.030E-08	0.00672
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)	0.000943			1.380E-09	2.6E-04
Total PCB Congeners (less dioxin-like)	2.591227			1.736E-05	2.904406
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	1.6E-06		ND		
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	5.5E-05		ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0133	ND	ND		ND
4,4'-DDD	0.0230	ND	ND	5.900E-08	0.0045
4,4'-DDE	0.119	0.103	ND	4.410E-08	0.0019
4,4'-DDT	ND	ND	ND		ND
Inorganics					
Arsenic	ND	ND	1.5E-03		16.9
Lead	ND	ND	5.2E-03		91.2
Mercury (total)	0.286	0.05	4.03E-05	7.57E-06	1.37
Mercury (inorganic)					
Mercury (organic)					

Table 5-30 Upper-bound Measured Concentrations for Green Bay

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.51	0.755		2.410E-06	0.213
Aroclor 1016	ND				ND
Aroclor 1221	ND				ND
Aroclor 1232	ND				ND
Aroclor 1242	0.526				0.279
Aroclor 1248	1.070				ND
Aroclor 1254	1.450				ND
Aroclor 1260	0.050				ND
Total PCB Aroclors (less 1016/1254)	1.06	0.755		0.00000241	0.213
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				4.240E-08	0.0092
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0052
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)				5.370E-09	1.57E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				1.280E-08	0.0193
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					5.2E-05
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)				2.320E-09	2.16E-04
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)				9.040E-10	5.62E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				1.700E-09	4.02E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				9.300E-09	7.27E-04
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				1.100E-08	0.00373
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)				4.090E-10	9.21E-05
Total PCB Congeners (less dioxin-like)				2.324E-06	0.1738681
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	3.8E-06				
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	3.5E-05				
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0603	0.0168			ND
4,4'-DDD	0.367	0.0111			ND
4,4'-DDE	0.422	0.145			ND
4,4'-DDT	0.027	ND			ND
Inorganics					
Arsenic		ND			6.39
Lead		ND	2.64E-04	4.42E-05	43.5
Mercury (total)	0.27	0.33	3.82E-04	2.27E-04	0.767
Mercury (inorganic)					
Mercury (organic)					

Table 5-31 Average Measured Concentrations for the Little Lake Butte des Morts Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.83	0.361	ND	1.110E-05	3.699
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.711		ND	1.400E-05	9.63
Aroclor 1248	0.119		ND	ND	0.732
Aroclor 1254	0.668		ND	ND	2.120
Aroclor 1260	0.171		ND	ND	0.711
Total PCB Aroclors (less 1016/1254)	2.162	0.361	0	1.110E-05	1.579
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.00146			1.980E-07	0.0113
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.0061				0.00663
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					1.93E-03
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.0235			7.460E-08	0.257
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.00252				0.0012
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	ND				3.20E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.00143				2.39E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	3.97E-04				6.45E-04
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					2.27E-03
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	ND				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.0034				0.0044
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.0103			2.810E-08	0.0662
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					8.50E-04
Total PCB Congeners (less dioxin-like)	2.780893			1.080E-05	3.343865
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	ND				2.46E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	1.8E-06				6.40E-05
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	0.0114			0.0059
4,4'-DDD	ND	ND			0.0178
4,4'-DDE	0.023	0.164			ND
4,4'-DDT	ND	ND			0.05
Inorganics					
Arsenic	ND	ND			4.65
Lead	ND	ND	1.450E-03	1.170E-04	172
Mercury (total)	0.107	ND	2.240E-03	ND	0.955
Mercury (inorganic)					
Mercury (organic)					

Table 5-32 Average Measured Concentrations for the Appleton to Little Rapids Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	3.98	0.515	ND	4.840E-06	1.398
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.315		ND	7.210E-06	4.7
Aroclor 1248	ND		ND	ND	ND
Aroclor 1254	0.34		ND	ND	0.340
Aroclor 1260	0.102		ND	ND	0.572
Total PCB Aroclors (less 1016/1254)	3.64	0.515	0	4.840E-06	1.058
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.250E-07	0.00646
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0152
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					3.50E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				8.080E-08	0.0542
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)				0.000000032	ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					5.20E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					1.50E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					1.19E-04
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				ND	2.10E-03
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				ND	0.0061
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				4.760E-08	0.0157
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					1.30E-04
Total PCB Congeners (less dioxin-like)				4.555E-06	1.295621
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)			ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	ND	ND		ND
4,4'-DDD	ND	ND	ND		0.0017
4,4'-DDE	0.0284	0.0807	ND		ND
4,4'-DDT	ND	ND	ND		0.0034
Inorganics					
Arsenic			ND		4.44
Lead			1.400E-03		75.6
Mercury (total)	0.27	0.0294	6.640E-05	0.000065	0.766
Mercury (inorganic)					
Mercury (organic)					

Table 5-33 Average Measured Concentrations for the Little Rapids to De Pere Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	0.615	0.838		1.130E-05	2.078
Aroclor 1016	ND			ND	ND
Aroclor 1221	ND			ND	ND
Aroclor 1232	ND			ND	ND
Aroclor 1242	0.243			1.200E-05	4.43
Aroclor 1248	0.316			ND	ND
Aroclor 1254	0.289			ND	0.421
Aroclor 1260	0.128			ND	0.164
Total PCB Aroclors (less 1016/1254)	0.326	0.838		1.130E-05	1.657
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.470E-07	0.0147
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0108
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					2.80E-03
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				5.540E-08	0.0334
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					0.00261
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					6.27E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					2.57E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					1.55E-03
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					1.85E-03
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)					0.0055
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				3.020E-08	0.0129
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					7.40E-04
Total PCB Congeners (less dioxin-like)				1.107E-05	1.987973
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					5.26E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)					8.14E-05
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND				ND
4,4'-DDD	0.00494				0.0028
4,4'-DDE	0.0426				0.0125
4,4'-DDT	ND				0.0165
Inorganics					
Arsenic					4.6
Lead			6.170E-04	1.210E-04	159
Mercury (total)	0.235		3.880E-03	0.00127	3.5
Mercury (inorganic)					
Mercury (organic)					

Table 5-34 Average Measured Concentrations for the De Pere to Green Bay Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.44	0.225		1.660E-05	2.959
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.631		ND	1.220E-05	4.39
Aroclor 1248	0.285		ND	ND	ND
Aroclor 1254	0.743		ND	ND	0.356
Aroclor 1260	0.226		ND	ND	0.331
Total PCB Aroclors (less 1016/1254)	1.697	0.225	0	1.660E-05	2.603
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.000511			1.610E-07	0.013
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.0115				0.00565
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)	0.000799			1.60E-08	1.38E-03
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.0314			4.940E-08	0.0127
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.000742			3.22E-08	0.000409
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	0.000154				2.38E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.00241			6.1E-09	1.03E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	5.83E-04			8.18E-10	8.00E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)	0.00104			2.0E-09	8.50E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	0.000194				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.00766			1.25E-08	0.0016
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.0158			1.610E-07	0.00391
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)	0.000139			8.31E-10	2.60E-04
Total PCB Congeners (less dioxin-like)	2.367068			1.616E-05	2.917893
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	0.0000016		ND		
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	1.5E-05		ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0102	ND	ND		ND
4,4'-DDD	0.0167	ND	ND	4.74E-08	0.0045
4,4'-DDE	0.0791	0.0421	ND	4.07E-08	0.0019
4,4'-DDT	ND	ND	ND		ND
Inorganics					
Arsenic	ND	ND	0.0015		10.1
Lead	ND	ND	3.110E-03		75.7
Mercury (total)	0.237	0.05	2.750E-05	0.00000487	1.03
Mercury (inorganic)					
Mercury (organic)					

Table 5-35 Average Measured Concentrations for Green Bay

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.11	0.328		2.180E-06	0.212
Aroclor 1016	ND				ND
Aroclor 1221	ND				ND
Aroclor 1232	ND				ND
Aroclor 1242	0.0341				0.164
Aroclor 1248	0.48				ND
Aroclor 1254	0.904				ND
Aroclor 1260	0.0327				ND
Total PCB Aroclors (less 1016/1254)	1.206	0.328			0.212
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				3.620E-08	0.00182
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.00118
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)				4.21E-09	1.01E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				1.150E-08	0.00709
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					4.13E-05
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)				2.1E-09	1.17E-04
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)				7.41E-10	4.72E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				9.4E-10	2.79E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				5.75E-09	0.0003
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				8.970E-09	0.00187
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)				3.31E-10	7.26E-05
Total PCB Congeners (less dioxin-like)				2.109E-06	0.1990959
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	0.00000372				
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	1.7E-05				
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0447	0.0125			ND
4,4'-DDD	0.0283	0.00933			ND
4,4'-DDE	0.301	0.0934			ND
4,4'-DDT	0.0215	ND			ND
Inorganics					
Arsenic		ND			3.81
Lead		ND	1.690E-04	4.410E-05	16.8
Mercury (total)	0.222	0.0895	1.900E-04	0.000131	0.29
Mercury (inorganic)					
Mercury (organic)					

Table 5-36 Cancer Evidence for Exposure to Commercial PCB Mixtures

Type of Study	Result	Mixture Composition
Lifetime Dietary Exposure	liver tumors in rats (Kimbrough *et al.*, 1975; Norback and Weltman, 1985; Schaeffer *et al.*, 1984)	60% chlorine
	promotion of benign tumors to malignant tumors (Norback and Weltman, 1985)	60% chlorine
	gastrointestinal tumors (NCI, 1978; Morgan *et al.*, 1981; Ward, 1985)	54% chlorine
Less-than-lifetime Dietary Exposure	precancerous liver lesions (Kimbrough and Linder, 1974; Ito *et al.*, 1973, 1974; Rao and Banerji, 1988)	42%–60% chlorine
Epidemiological	capacitor manufacturing workers had increased mortality from malignant melanoma and liver, gall bladder, gastrointestinal tract, and biliary tract cancer (Brown, 1987; Sinks *et al.*, 1992; Gustavsson *et al.*, 1986)	41%–54% chlorine
	petrochemical refinery workers had increased mortality from malignant melanoma (Bahn *et al.*, 1976)	54% chlorine
	electric utility workers had increased mortality from malignant melanoma and brain cancer (Loomis, *et al.*, 1997)	PCBs
Case-control	non-Hodgkin lymphoma (Hardell *et al.*, 1996; Rotham *et al.*, 1997)	PCBs in adipose tissue and serum
	mortality from liver and lung cancer in general population following consumption of PCB- and dibenzofuran-contaminated rice oil (Masuda, 1994)	heated PCBs above 270 ˚C

Table 5-37 PCB Cancer Slope Factors by Persistence and Route of Exposure

PCB Mixture Characteristic	Ingestion of Fish/Waterfowl	Ingestion of Sediment	Dermal Contact with Sediment	Ingestion of Water	Dermal Contact with Water	Inhalation of Volatilized Compounds
Highest Risk and Persistence						
Central Tendency Slope	1	1	1	0.3	0.3	0.3
Upper-bound Slope	2	2	2	0.4	0.4	0.4
Lowest Risk and Persistence						
Central Tendency Slope	0.04	0.04	0.04	0.04	0.04	0.04
Upper-bound Slope	0.07	0.07	0.07	0.07	0.07	0.07

Note:

All values have units of $(mg/kg\text{-}day)^{-1}$.

Table 5-38 Toxicity Equivalency Factors for Dioxin-like PCBs

PCBs	U.S. EPA TEF Value (a)	WHO TEF Value (b)
Non-ortho Congeners		
3,3',4,4'-TeCB (PCB 77)	0.0005	0.0001
3,4,4',5-TeCB (PCB 81)	NA	0.0001
3,3',4,4',5-PeCB (PCB 126)	0.1	0.1
3,3',4,4',5,5'-HxCB (PCB 169)	0.01	0.01
Mono-ortho Congeners		
2,3,3',4,4'-PeCB (PCB 105)	0.0001	0.0001
2,3,4,4',5-PeCB (PCB 114)	0.0005	0.0005
2,3',4,4',5-PeCB (PCB 118)	0.0001	0.0001
2',3,4,4',5-PeCB (PCB 123)	0.0001	0.0001
2,3,3',4,4',5-HxCB (PCB 156)	0.0005	0.0005
2,3,3',4,4',5'-HxCB (PCB 157)	0.0005	0.0005
2,3',4,4',5,5'-HxCB (PCB 167)	0.00001	0.00001
2,3,3',4,4',5,5'-HpCB (PCB 189)	0.0001	0.0001
Di-ortho Congeners		
2,2',3,3',4,4',5-HpCB (PCB 170)	0.0001	NA
2,2',3,4,4',5,5'-HpCB (PCB 180)	0.00001	NA

Note:

NA indicates a TEF is not available.

Sources:

a. EPA, 1996a.

b. WHO, 1997.

Table 5-39 Summary of Dioxin and Furan Toxicity Equivalency Factors

Congeners	U.S. EPA TEF Value (a)	WHO TEF Value (b)
Dioxins		
2,3,7,8-TCDD	1	1
2,3,7,8-PCDD	0.5	1
2,3,7,8-HxCDD	0.1	0.1
2,3,7,8,-HpCDD	0.01	0.01
OCDD	0.001	0.0001
Furans		
2,3,7,8-TCDF	0.1	0.1
1,2,3,7,8-PCDF	0.05	0.05
2,3,4,7,8-PCDF	0.5	0.5
2,3,7,8-HxCDF	0.1	0.1
2,3,7,8-HpCDF	0.01	0.01
OCDF	0.001	0.0001

Sources:

a. EPA, 1989.
b. WHO, 1997.

Table 5-40 Summary of Cancer Slope Factors by Route of Exposure

Chemical of Potential Concern	Oral Soil/Sed CSFslo $(mg/kg\text{-}day)^{-1}$	Oral Water CSFwo $(mg/kg\text{-}day)^{-1}$	Oral Fish/Food CSFfo $(mg/kg\text{-}day)^{-1}$	Dermal Soil/Sed CSFsld $(mg/kg\text{-}day)^{-1}$	Dermal Water CSFwd $(mg/kg\text{-}day)^{-1}$	Inhalation Vapor CSFavi $(mg/kg\text{-}day)^{-1}$	Inhalation Particulate CSFapi $(mg/kg\text{-}day)^{-1}$
PCBs							
Total PCBs	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1016	7.00E-02	7.00E-02	7.00E-02	7.00E-02	7.00E-02	7.00E-02	7.00E-02
Aroclor 1221	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1232	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1242	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1248	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1254	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1260	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
3,3',4,4'-TeCB (PCB-77)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3,3',4,4'-PeCB (PCB-105)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
2,3,4,4',5-PeCB (PCB-114)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3',4,4',5-PeCB (PCB-118)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
2',3,4,4',5-PeCB (PCB-123)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
3,3',4,4',5-PeCB (PCB-126)	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
2,3,3',4,4',5-HxCB (PCB-156)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3,3',4,4',5'-HxCB (PCB-157)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3',4,4',5,5'-HxCB (PCB-167)	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00
3,3',4,4',5,5'-HxCB (PCB-169)	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
2,2',3,3',4,4',5-HpCB (PCB-170)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
2,2',3,4,4',5,5'-HpCB (PCB-180)	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00
2,3,3',4,4',5,5'-HpCB (PCB-189)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
Chlorinated Dioxins							
2,3,7,8-TCDD	1.50E+05	1.50E+05	1.50E+05	1.50E+05	1.50E+05	1.50E+05	1.50E+05
1,2,3,7,8-PCDD	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04
1,2,3,4,7,8-HxCDD	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,6,7,8-HxCDD	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,7,8,9-HxCDD	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,4,6,7,8-HpCDD	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
OCDD	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02
Chlorinated Furans							
2,3,7,8-TCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,7,8-PCDF	7.50E+03	7.50E+03	7.50E+03	7.50E+03	7.50E+03	7.50E+03	7.50E+03
2,3,4,7,8-PCDF	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04
1,2,3,4,7,8-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,6,7,8-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,7,8,9-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
2,3,4,6,7,8-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,4,6,7,8-HpCDF	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
1,2,3,4,7,8,9-HpCDF	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
OCDF	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02
Organochlorine Pesticides							
Dieldrin	1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.61E+01	1.61E+01
4,4'-DDD	2.40E-01	2.40E-01	2.40E-01	2.40E-01	2.40E-01	NA	NA
4,4'-DDE	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	NA	NA
4,4'-DDT	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01
Inorganics							
Arsenic	1.50E+00	1.50E+00	1.50E+00	1.58E+00	1.58E+00	1.51E+01	1.51E+01
Lead	NA	NA	NA	NA	NA	NA	NA
Mercury (total)	NA	NA	NA	NA	NA	NA	NA
Mercury (inorganic)	NA	NA	NA	NA	NA	NA	NA
Mercury (organic)	NA	NA	NA	NA	NA	NA	NA

Table 5-41 Summary of Reference Doses by Route of Exposure

Chemical of Potential Concern	Oral Soil/Sed RfDcslo (mg/kg-day)	Oral Water RfDcwo (mg/kg-day)	Oral Fish/Food RfDcfo (mg/kg-day)	Dermal Soil/Sed RfDcsd (mg/kg-day)	Dermal Water RfDcwd (mg/kg-day)	Inhalation Vapor RfDcavi (mg/kg-day)	Inhalation Particulate RfDcapi (mg/kg-day)
PCBs							
Total PCBs	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1016	7.00E-05	7.00E-05	7.00E-05	7.00E-05	7.00E-05	NA	NA
Aroclor 1221	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1232	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1242	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1248	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1254	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1260	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
3,3',4,4'-TeCB (PCB-77)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4'-PeCB (PCB-105)	NA	NA	NA	NA	NA	NA	NA
2,3,4,4',5-PeCB (PCB-114)	NA	NA	NA	NA	NA	NA	NA
2,3',4,4',5-PeCB (PCB-118)	NA	NA	NA	NA	NA	NA	NA
2',3,4,4',5-PeCB (PCB-123)	NA	NA	NA	NA	NA	NA	NA
3,3',4,4',5-PeCB (PCB-126)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4',5-HxCB (PCB-156)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4',5'-HxCB (PCB-157)	NA	NA	NA	NA	NA	NA	NA
2,3',4,4',5,5'-HxCB (PCB-167)	NA	NA	NA	NA	NA	NA	NA
3,3',4,4',5,5'-HxCB (PCB-169)	NA	NA	NA	NA	NA	NA	NA
2,2',3,3',4,4',5-HpCB (PCB-170)	NA	NA	NA	NA	NA	NA	NA
2,2',3,4,4',5,5'-HpCB (PCB-180)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4',5,5'-HpCB (PCB-189)	NA	NA	NA	NA	NA	NA	NA
Chlorinated Dioxins							
2,3,7,8-TCDD	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	NA	NA
1,2,3,7,8-PCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8-HxCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,6,7,8-HxCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8,9-HxCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,6,7,8-HpCDD	NA	NA	NA	NA	NA	NA	NA
OCDD	NA	NA	NA	NA	NA	NA	NA
Chlorinated Furans							
2,3,7,8-TCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8-PCDF	NA	NA	NA	NA	NA	NA	NA
2,3,4,7,8-PCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8-HxCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,6,7,8-HxCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8,9-HxCDF	NA	NA	NA	NA	NA	NA	NA
2,3,4,6,7,8-HxCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,6,7,8-HpCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8,9-HpCDF	NA	NA	NA	NA	NA	NA	NA
OCDF	NA	NA	NA	NA	NA	NA	NA
Organochlorine Pesticides							
Dieldrin	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05	NA	NA
4,4'-DDD	NA	NA	NA	NA	NA	NA	NA
4,4'-DDE	NA	NA	NA	NA	NA	NA	NA
4,4'-DDT	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	NA	NA
Inorganics							
Arsenic	3.00E-04	3.00E-04	3.00E-04	2.85E-04	2.85E-04	NA	NA
Lead	NA	NA	NA	NA	NA	NA	NA
Mercury (total)	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	8.60E-05	8.60E-05
Mercury (inorganic)	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	8.60E-05	8.60E-05
Mercury (organic)	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	NA	NA

Table 5-42 Total Cancer Risks for the Recreational Angler (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.0E-03	2.8E-03	4.1E-04	1.5E-03	1.4E-03
Total Dioxins/Furans	7.4E-06	0.0E+00	0.0E+00	2.9E-04	3.0E-04
Total Pesticides	7.2E-06	6.5E-06	7.6E-06	7.1E-05	3.3E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.1E-07	0.0E+00
Total	**2.0E-03**	**2.8E-03**	**4.2E-04**	**1.9E-03**	**2.0E-03**
Risks by Pathway					
Ingestion of Fish	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	3.2E-09	2.0E-09	2.6E-09	1.1E-07	5.1E-10
Inhalation of Indoor and Outdoor Air	1.7E-08	9.5E-09	1.2E-08	1.8E-08	5.3E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.0E-03**	**2.8E-03**	**4.2E-04**	**1.9E-03**	**2.0E-03**
Percent of Total for Chemical Group					
Total PCBs	99.27%	99.76%	98.18%	80.65%	68.57%
Total Dioxins/Furans	0.37%	0.00%	0.00%	15.56%	14.96%
Total Pesticides	0.36%	0.24%	1.82%	3.78%	16.47%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.0E-03	2.8E-03	4.1E-04	1.5E-03	1.4E-03
Total PCBs using Aroclor Data	1.5E-03	6.7E-04	1.1E-03	1.3E-03	1.7E-03
Total PCBs using Congener Data	4.5E-04	3.6E-08	2.7E-08	6.0E-03	1.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.2%	257.9%	84.7%	123.4%
Total PCBs using Congener Data	23.0%	0.0%	0.0%	398.5%	0.0%

Table 5-43 Total Hazard Indices for the Recreational Angler (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	73.936	103.949	15.428	56.700	51.563
Total Dioxins/Furans	0.000	0.000	0.000	0.657	1.561
Total Pesticides	0.000	0.000	0.000	0.109	0.518
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	2.300	3.134	2.464	2.350	2.239
Total	**76.236**	**107.083**	**17.893**	**59.817**	**55.881**
Hazard Indices by Pathway					
Ingestion of Fish	75.907	107.079	17.786	59.816	55.861
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.006	0.000	0.006	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.323	0.004	0.101	0.000	0.020
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**76.236**	**107.083**	**17.893**	**59.817**	**55.881**
Percent of Total for Chemical Group					
Total PCBs	96.98%	97.07%	86.23%	94.79%	92.27%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.10%	2.79%
Total Pesticides	0.00%	0.00%	0.00%	0.18%	0.93%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	3.02%	2.93%	13.77%	3.93%	4.01%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.57%	100.00%	99.40%	100.00%	99.96%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.01%	0.00%	0.03%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.42%	0.00%	0.56%	0.00%	0.04%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	73.936	103.949	15.428	56.700	51.563
Total PCBs using Aroclor Data	55.467	25.104	39.792	48.051	63.604
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.2%	257.9%	84.7%	123.4%

Table 5-44 Total Cancer Risks for the Recreational Angler (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.5E-03	2.2E-03	3.4E-04	1.3E-03	1.3E-03
Total Dioxins/Furans	7.4E-06	0.0E+00	0.0E+00	1.3E-04	2.2E-04
Total Pesticides	2.1E-06	2.6E-06	4.3E-06	5.3E-05	2.3E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.1E-07	0.0E+00
Total	**1.6E-03**	**2.2E-03**	**3.4E-04**	**1.5E-03**	**1.8E-03**
Risks by Pathway					
Ingestion of Fish	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	2.3E-09	1.0E-09	2.4E-09	1.2E-07	4.6E-10
Inhalation of Indoor and Outdoor Air	1.3E-08	4.9E-09	1.1E-08	3.2E-08	4.8E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**1.6E-03**	**2.2E-03**	**3.4E-04**	**1.5E-03**	**1.8E-03**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.5E-03	2.2E-03	3.4E-04	1.3E-03	1.3E-03
Total PCBs using Aroclor Data	9.1E-04	4.1E-04	5.3E-04	1.0E-03	1.0E-03
Total PCBs using Congener Data	2.2E-04	2.4E-08	2.4E-08	1.0E-03	1.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-45 Total Hazard Indices for the Recreational Angler (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	58.076	81.659	12.635	50.127	49.057
Total Dioxins/Furans	0.000	0.000	0.000	0.657	1.528
Total Pesticides	0.000	0.000	0.000	0.084	0.402
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.982	2.224	1.985	1.948	2.165
Total	**59.058**	**83.883**	**14.619**	**52.816**	**53.152**
Hazard Indices by Pathway					
Ingestion of Fish	58.955	83.880	14.565	52.814	53.140
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.002	0.000	0.003	0.002	0.000
Inhalation of Indoor and Outdoor Air	0.101	0.003	0.051	0.000	0.012
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**59.058**	**83.883**	**14.619**	**52.816**	**53.152**
Percent of Total for Chemical Group					
Total PCBs	98.34%	97.35%	86.42%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.66%	2.65%	13.58%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.83%	100.00%	99.63%	100.00%	99.98%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.17%	0.00%	0.35%	0.00%	0.02%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	58.076	81.659	12.635	50.127	49.057
Total PCBs using Aroclor Data	34.287	15.551	20.050	38.724	38.786
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-46 Total Cancer Risks for the Recreational Angler (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.4E-04	3.3E-04	5.1E-05	2.0E-04	2.0E-04
Total Dioxins/Furans	1.1E-06	0.0E+00	0.0E+00	1.9E-05	3.4E-05
Total Pesticides	3.3E-07	4.0E-07	6.5E-07	8.1E-06	3.4E-05
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.7E-08	0.0E+00
Total	**2.4E-04**	**3.3E-04**	**5.2E-05**	**2.3E-04**	**2.7E-04**
Risks by Pathway					
Ingestion of Fish	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	3.0E-10	1.3E-10	3.1E-10	1.8E-08	6.0E-11
Inhalation of Indoor and Outdoor Air	1.9E-09	7.5E-10	1.7E-09	4.8E-09	7.3E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.4E-04**	**3.3E-04**	**5.2E-05**	**2.3E-04**	**2.7E-04**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.4E-04	3.3E-04	5.1E-05	2.0E-04	2.0E-04
Total PCBs using Aroclor Data	1.4E-04	6.3E-05	8.2E-05	1.6E-04	1.6E-04
Total PCBs using Congener Data	3.3E-05	3.5E-09	3.6E-09	1.6E-04	2.7E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-47 Total Hazard Indices for the Recreational Angler (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	14.765	20.761	3.212	12.744	12.472
Total Dioxins/Furans	0.000	0.000	0.000	0.167	0.389
Total Pesticides	0.000	0.000	0.000	0.021	0.102
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.250	0.565	0.505	0.495	0.550
Total	**15.015**	**21.326**	**3.717**	**13.428**	**13.513**
Hazard Indices by Pathway					
Ingestion of Fish	14.989	21.325	3.703	13.427	13.510
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.001	0.000	0.001	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.026	0.001	0.013	0.000	0.003
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**15.015**	**21.326**	**3.717**	**13.428**	**13.513**
Percent of Total for Chemical Group					
Total PCBs	98.34%	97.35%	86.43%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.66%	2.65%	13.57%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.83%	100.00%	99.63%	100.00%	99.98%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.17%	0.00%	0.35%	0.00%	0.02%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	14.765	20.761	3.212	12.744	12.472
Total PCBs using Aroclor Data	8.717	3.954	5.098	9.845	9.861
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-48 Total Cancer Risks for the High-intake Fish Consumer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.7E-03	3.8E-03	5.6E-04	2.1E-03	2.0E-03
Total Dioxins/Furans	1.0E-05	0.0E+00	0.0E+00	4.0E-04	4.1E-04
Total Pesticides	9.8E-06	8.9E-06	1.1E-05	9.8E-05	4.5E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.5E-07	0.0E+00
Total	**2.7E-03**	**3.8E-03**	**5.7E-04**	**2.6E-03**	**2.9E-03**
Risks by Pathway					
Ingestion of Fish	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	4.4E-09	2.7E-09	3.7E-09	1.6E-07	7.1E-10
Inhalation of Indoor and Outdoor Air	1.6E-08	8.6E-09	1.2E-08	3.3E-08	4.9E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.7E-03**	**3.8E-03**	**5.7E-04**	**2.6E-03**	**2.9E-03**
Percent of Total for Chemical Group					
Total PCBs	99.27%	99.77%	98.17%	80.64%	70.34%
Total Dioxins/Furans	0.37%	0.00%	0.00%	15.55%	14.14%
Total Pesticides	0.36%	0.23%	1.83%	3.80%	15.52%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.7E-03	3.8E-03	5.6E-04	2.1E-03	2.0E-03
Total PCBs using Aroclor Data	2.0E-03	9.2E-04	1.5E-03	1.8E-03	5.1E-03
Total PCBs using Congener Data	6.2E-04	3.7E-08	2.8E-08	8.3E-03	2.0E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.1%	258.1%	84.9%	247.4%
Total PCBs using Congener Data	23.0%	0.0%	0.0%	398.3%	0.0%

Table 5-49 Total Hazard Indices for the High-intake Fish Consumer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	101.316	142.472	21.142	77.727	76.683
Total Dioxins/Furans	0.000	0.000	0.000	0.901	2.139
Total Pesticides	0.000	0.000	0.000	0.151	0.816
Arsenic	0.000	0.000	0.000	0.001	0.000
Mercury	3.004	4.294	3.331	3.222	6.997
Total	**104.320**	**146.766**	**24.473**	**82.001**	**86.635**
Hazard Indices by Pathway					
Ingestion of Fish	104.017	146.762	24.373	81.997	86.616
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.008	0.001	0.008	0.003	0.001
Inhalation of Indoor and Outdoor Air	0.295	0.003	0.092	0.002	0.018
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**104.320**	**146.766**	**24.473**	**82.001**	**86.635**
Percent of Total for Chemical Group					
Total PCBs	97.12%	97.07%	86.39%	94.79%	88.51%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.10%	2.47%
Total Pesticides	0.00%	0.00%	0.00%	0.18%	0.94%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	2.88%	2.93%	13.61%	3.93%	8.08%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.71%	100.00%	99.59%	99.99%	99.98%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.01%	0.00%	0.03%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.28%	0.00%	0.38%	0.00%	0.02%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	101.316	142.472	21.142	77.727	76.683
Total PCBs using Aroclor Data	76.008	34.401	54.557	65.958	189.737
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.1%	258.0%	84.9%	247.4%

Table 5-50 Total Cancer Risks for the High-intake Fish Consumer (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.1E-03	3.0E-03	4.6E-04	1.8E-03	1.8E-03
Total Dioxins/Furans	1.0E-05	0.0E+00	0.0E+00	1.8E-04	3.1E-04
Total Pesticides	2.9E-06	3.6E-06	5.9E-06	7.3E-05	3.1E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.5E-07	0.0E+00
Total	**2.1E-03**	**3.0E-03**	**4.7E-04**	**2.1E-03**	**2.4E-03**
Risks by Pathway					
Ingestion of Fish	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	3.2E-09	1.4E-09	3.3E-09	1.6E-07	6.4E-10
Inhalation of Indoor and Outdoor Air	1.1E-08	4.5E-09	1.0E-08	2.9E-08	4.4E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.1E-03**	**3.0E-03**	**4.7E-04**	**2.1E-03**	**2.4E-03**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.1E-03	3.0E-03	4.6E-04	1.8E-03	1.8E-03
Total PCBs using Aroclor Data	1.3E-03	5.7E-04	7.3E-04	1.4E-03	1.4E-03
Total PCBs using Congener Data	3.0E-04	2.4E-08	2.5E-08	1.4E-03	1.7E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-51 Total Hazard Indices for the High-intake Fish Consumer (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	79.583	111.900	17.313	68.690	67.224
Total Dioxins/Furans	0.000	0.000	0.000	0.901	2.094
Total Pesticides	0.000	0.000	0.000	0.115	0.550
Arsenic	0.000	0.000	0.000	0.001	0.000
Mercury	1.299	3.046	2.697	2.669	2.961
Total	**80.883**	**114.946**	**20.010**	**72.375**	**72.830**
Hazard Indices by Pathway					
Ingestion of Fish	80.787	114.943	19.959	72.373	72.819
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.003	0.000	0.005	0.002	0.000
Inhalation of Indoor and Outdoor Air	0.092	0.002	0.046	0.000	0.011
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**80.883**	**114.946**	**20.010**	**72.375**	**72.830**
Percent of Total for Chemical Group					
Total PCBs	98.39%	97.35%	86.52%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.61%	2.65%	13.48%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.88%	100.00%	99.74%	100.00%	99.99%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.11%	0.00%	0.23%	0.00%	0.01%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	79.583	111.900	17.313	68.690	67.224
Total PCBs using Aroclor Data	46.984	21.310	27.476	53.065	53.149
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-52 Total Cancer Risks for the High-intake Fish Consumer (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	3.3E-04	4.7E-04	7.2E-05	2.9E-04	2.8E-04
Total Dioxins/Furans	1.6E-06	0.0E+00	0.0E+00	2.7E-05	4.8E-05
Total Pesticides	4.6E-07	5.7E-07	9.2E-07	1.1E-05	4.9E-05
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	2.4E-08	0.0E+00
Total	**3.4E-04**	**4.7E-04**	**7.3E-05**	**3.3E-04**	**3.8E-04**
Risks by Pathway					
Ingestion of Fish	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	4.3E-10	1.9E-10	4.4E-10	2.5E-08	8.4E-11
Inhalation of Indoor and Outdoor Air	1.8E-09	7.0E-10	1.6E-09	4.6E-09	6.9E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**3.4E-04**	**4.7E-04**	**7.3E-05**	**3.3E-04**	**3.8E-04**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	3.3E-04	4.7E-04	7.2E-05	2.9E-04	2.8E-04
Total PCBs using Aroclor Data	2.0E-04	8.9E-05	1.1E-04	2.2E-04	2.2E-04
Total PCBs using Congener Data	4.7E-05	3.6E-09	3.7E-09	2.2E-04	2.6E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-53 Total Hazard Indices for the High-intake Fish Consumer (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	20.814	29.266	4.528	17.965	17.582
Total Dioxins/Furans	0.000	0.000	0.000	0.236	0.548
Total Pesticides	0.000	0.000	0.000	0.030	0.144
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.340	0.797	0.705	0.698	0.774
Total	**21.154**	**30.063**	**5.233**	**18.929**	**19.048**
Hazard Indices by Pathway					
Ingestion of Fish	21.129	30.062	5.220	18.928	19.045
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.001	0.000	0.001	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.024	0.001	0.012	0.000	0.003
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**21.154**	**30.063**	**5.233**	**18.929**	**19.048**
Percent of Total for Chemical Group					
Total PCBs	98.39%	97.35%	86.52%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.61%	2.65%	13.48%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.88%	100.00%	99.75%	100.00%	99.99%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.11%	0.00%	0.23%	0.00%	0.01%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	20.814	29.266	4.528	17.965	17.582
Total PCBs using Aroclor Data	12.288	5.573	7.186	13.878	13.900
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-54 Total Cancer Risks for the Hunter (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	4.4E-05	5.2E-05	8.3E-05	5.4E-05	5.1E-05
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	1.6E-05	1.4E-06	0.0E+00	1.2E-06	1.1E-05
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.4E-08	0.0E+00
Total	**6.1E-05**	**5.3E-05**	**8.3E-05**	**5.5E-05**	**6.1E-05**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
Ingestion/Dermal Contact with Water	4.1E-10	2.5E-10	3.3E-10	1.4E-08	6.5E-11
Inhalation of Indoor and Outdoor Air	2.9E-09	1.6E-09	2.1E-09	3.1E-09	9.0E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**6.1E-05**	**5.3E-05**	**8.3E-05**	**5.5E-05**	**6.1E-05**
Percent of Total for Chemical Group					
Total PCBs	73.24%	97.41%	100.00%	97.83%	82.48%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	26.76%	2.59%	0.00%	2.14%	17.52%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.03%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	99.99%	100.00%	100.00%	99.97%	100.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.03%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.01%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	4.4E-05	5.2E-05	8.3E-05	5.4E-05	5.1E-05
Total PCBs using Aroclor Data	4.0E-09	1.5E-09	2.7E-09	2.7E-09	0.0E+00
Total PCBs using Congener Data	6.9E-09	5.7E-09	4.3E-09	6.3E-09	3.0E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%
Total PCBs using Congener Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-55 Total Hazard Indices for the Hunter (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	1.662	1.949	3.098	2.015	1.901
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.016	0.000	0.000	0.000	0.017
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.055	0.022	0.018	0.025	0.170
Total	**1.733**	**1.971**	**3.115**	**2.040**	**2.088**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	1.678	1.970	3.098	2.040	2.085
Ingestion/Dermal Contact with Water	0.001	0.000	0.001	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.054	0.001	0.017	0.000	0.003
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**1.733**	**1.971**	**3.115**	**2.040**	**2.088**
Percent of Total for Chemical Group					
Total PCBs	95.91%	98.91%	99.43%	98.76%	91.07%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.91%	0.00%	0.00%	0.00%	0.81%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	3.18%	1.09%	0.57%	1.24%	8.12%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	96.82%	99.97%	99.43%	99.99%	99.84%
Ingestion/Dermal Contact with Water	0.04%	0.00%	0.02%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	3.14%	0.03%	0.55%	0.00%	0.16%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	1.662	1.949	3.098	2.015	1.901
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-56 Total Cancer Risks for the Hunter (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.4E-05	3.5E-05	3.0E-05	1.5E-05	2.2E-05
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	8.0E-06	9.2E-07	0.0E+00	4.8E-07	7.6E-06
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.4E-08	0.0E+00
Total	**3.2E-05**	**3.6E-05**	**3.0E-05**	**1.6E-05**	**3.0E-05**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
Ingestion/Dermal Contact with Water	3.0E-10	1.3E-10	3.1E-10	1.5E-08	5.9E-11
Inhalation of Indoor and Outdoor Air	2.1E-09	8.3E-10	1.9E-09	5.4E-09	8.2E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**3.2E-05**	**3.6E-05**	**3.0E-05**	**1.6E-05**	**3.0E-05**
Percent of Total for Chemical Group					
Total PCBs	75.16%	97.41%	100.00%	96.84%	74.38%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	24.84%	2.59%	0.00%	3.07%	25.62%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.09%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	99.99%	100.00%	99.99%	99.87%	100.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.09%	0.00%
Inhalation of Indoor and Outdoor Air	0.01%	0.00%	0.01%	0.03%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.4E-05	3.5E-05	3.0E-05	1.5E-05	2.2E-05
Total PCBs using Aroclor Data	2.9E-09	1.4E-09	2.2E-09	2.4E-09	0.0E+00
Total PCBs using Congener Data	5.7E-09	3.8E-09	3.9E-09	6.0E-09	2.9E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%
Total PCBs using Congener Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-57 Total Hazard Indices for the Hunter (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.909	1.297	1.137	0.567	0.826
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.012	0.000	0.000	0.000	0.012
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.017	0.015	0.009	0.025	0.002
Total	**0.938**	**1.312**	**1.146**	**0.593**	**0.840**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.921	1.312	1.137	0.592	0.838
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.017	0.000	0.009	0.000	0.002
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.938**	**1.312**	**1.146**	**0.593**	**0.840**
Percent of Total for Chemical Group					
Total PCBs	96.93%	98.84%	99.22%	95.74%	98.32%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	1.23%	0.00%	0.00%	0.00%	1.44%
Arsenic	0.00%	0.00%	0.00%	0.01%	0.00%
Mercury	1.84%	1.16%	0.78%	4.26%	0.24%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	98.15%	99.96%	99.21%	99.96%	99.76%
Ingestion/Dermal Contact with Water	0.03%	0.00%	0.04%	0.04%	0.00%
Inhalation of Indoor and Outdoor Air	1.82%	0.03%	0.75%	0.01%	0.23%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.909	1.297	1.137	0.567	0.826
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-58 Total Cancer Risks for the Hunter (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	7.3E-06	1.0E-05	9.1E-06	4.5E-06	6.6E-06
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	2.4E-06	2.8E-07	0.0E+00	1.4E-07	2.3E-06
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	4.2E-09	0.0E+00
Total	**9.7E-06**	**1.1E-05**	**9.1E-06**	**4.7E-06**	**8.9E-06**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Ingestion/Dermal Contact with Water	7.5E-11	3.3E-11	7.8E-11	4.4E-09	1.5E-11
Inhalation of Indoor and Outdoor Air	6.4E-10	2.5E-10	5.8E-10	1.6E-09	2.4E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**9.7E-06**	**1.1E-05**	**9.1E-06**	**4.7E-06**	**8.9E-06**
Percent of Total for Chemical Group					
Total PCBs	75.16%	97.41%	100.00%	96.84%	74.38%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	24.84%	2.59%	0.00%	3.07%	25.62%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.09%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	99.99%	100.00%	99.99%	99.87%	100.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.09%	0.00%
Inhalation of Indoor and Outdoor Air	0.01%	0.00%	0.01%	0.03%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	7.3E-06	1.0E-05	9.1E-06	4.5E-06	6.6E-06
Total PCBs using Aroclor Data	8.8E-10	4.0E-10	6.7E-10	7.0E-10	0.0E+00
Total PCBs using Congener Data	1.7E-09	1.1E-09	1.1E-09	1.8E-09	8.7E-10
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%
Total PCBs using Congener Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-59 Total Hazard Indices for the Hunter (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.455	0.649	0.568	0.284	0.413
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.006	0.000	0.000	0.000	0.006
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.009	0.008	0.004	0.013	0.001
Total	**0.469**	**0.656**	**0.573**	**0.296**	**0.420**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.460	0.656	0.568	0.296	0.419
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.009	0.000	0.004	0.000	0.001
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.469**	**0.656**	**0.573**	**0.296**	**0.420**
Percent of Total for Chemical Group					
Total PCBs	96.93%	98.84%	99.22%	95.74%	98.32%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	1.23%	0.00%	0.00%	0.00%	1.44%
Arsenic	0.00%	0.00%	0.00%	0.01%	0.00%
Mercury	1.84%	1.16%	0.78%	4.26%	0.24%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	98.16%	99.96%	99.22%	99.96%	99.76%
Ingestion/Dermal Contact with Water	0.03%	0.00%	0.04%	0.03%	0.00%
Inhalation of Indoor and Outdoor Air	1.82%	0.03%	0.75%	0.01%	0.23%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.455	0.649	0.568	0.284	0.413
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-60 Total Cancer Risks for the Drinking Water User (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.6E-07	1.6E-07	2.1E-07	3.1E-07	4.2E-08
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	0.0E+00	0.0E+00	0.0E+00	7.6E-10	0.0E+00
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	3.8E-05	0.0E+00
Total	**2.6E-07**	**1.6E-07**	**2.1E-07**	**3.8E-05**	**4.2E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.1E-08
Inhalation of Indoor and Outdoor Air	7.2E-09	4.4E-09	5.8E-09	8.3E-09	1.1E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.6E-07**	**1.6E-07**	**2.1E-07**	**3.8E-05**	**4.2E-08**
Percent of Total for Chemical Group					
Total PCBs	100.00%	100.00%	100.00%	0.80%	100.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	99.19%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	97.28%	97.28%	97.28%	99.98%	97.28%
Inhalation of Indoor and Outdoor Air	2.72%	2.72%	2.72%	0.02%	2.72%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.6E-07	1.6E-07	2.1E-07	3.1E-07	4.2E-08
Total PCBs using Aroclor Data	2.0E-07	8.5E-08	1.5E-07	1.5E-07	0.0E+00
Total PCBs using Congener Data	7.9E-07	7.0E-07	5.4E-07	7.1E-07	1.8E-07
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	75.5%	51.9%	70.2%	48.1%	0.0%
Total PCBs using Congener Data	299.3%	426.8%	255.4%	232.9%	424.1%

Table 5-61 Total Hazard Indices for the Drinking Water User (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.210	0.000
Mercury	3.476	0.044	3.154	0.017	0.175
Total	**3.562**	**0.097**	**3.223**	**0.327**	**0.189**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	3.084	0.091	3.055	0.326	0.174
Inhalation of Indoor and Outdoor Air	0.478	0.006	0.169	0.001	0.015
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**3.562**	**0.097**	**3.223**	**0.327**	**0.189**
Percent of Total for Chemical Group					
Total PCBs	2.41%	54.78%	2.14%	30.42%	7.16%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	64.26%	0.00%
Mercury	97.59%	45.22%	97.86%	5.32%	92.84%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	86.59%	93.79%	94.77%	99.85%	91.96%
Inhalation of Indoor and Outdoor Air	13.41%	6.21%	5.23%	0.15%	8.04%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total PCBs using Aroclor Data	0.061	0.026	0.045	0.045	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	70.6%	48.5%	65.6%	44.9%	0.0%

Table 5-62 Total Hazard Indices for the Drinking Water User (RME with Upper-bound Concentrations and Recent Mercury Data)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.210	0.000
Mercury	0.089	0.044	0.089	0.017	0.175
Total	**0.175**	**0.097**	**0.158**	**0.327**	**0.189**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.162	0.091	0.146	0.326	0.174
Inhalation of Indoor and Outdoor Air	0.012	0.006	0.012	0.001	0.015
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.175**	**0.097**	**0.158**	**0.327**	**0.189**
Percent of Total for Chemical Group					
Total PCBs	49.23%	54.78%	43.81%	30.42%	7.16%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	64.26%	0.00%
Mercury	50.77%	45.22%	56.19%	5.32%	92.84%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	93.02%	93.79%	92.28%	99.85%	91.96%
Inhalation of Indoor and Outdoor Air	6.98%	6.21%	7.72%	0.15%	8.04%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total PCBs using Aroclor Data	0.061	0.026	0.045	0.045	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	70.6%	48.5%	65.6%	44.9%	0.0%

Table 5-63 Total Cancer Risks for the Local Resident (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**1.2E-07**	**6.8E-08**	**8.8E-08**	**1.3E-07**	**3.8E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Inhalation of Indoor and Outdoor Air	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**1.2E-07**	**6.8E-08**	**8.8E-08**	**1.3E-07**	**3.8E-08**
Percent of Total for Chemical Group					
Total PCBs	100.00%	100.00%	100.00%	100.00%	100.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	100.00%	100.00%	100.00%	100.00%	100.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Total PCBs using Aroclor Data	1.6E-07	6.0E-08	1.1E-07	1.1E-07	0.0E+00
Total PCBs using Congener Data	2.4E-07	2.0E-07	1.5E-07	2.2E-07	1.1E-07
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	130.0%	89.3%	120.8%	82.8%	0.0%
Total PCBs using Congener Data	192.4%	291.2%	166.0%	165.7%	298.6%

Table 5-64 Total Hazard Indices for the Local Resident (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	3.823	0.043	1.194	0.004	0.237
Total	**3.823**	**0.043**	**1.194**	**0.004**	**0.237**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	3.823	0.043	1.194	0.004	0.237
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**3.823**	**0.043**	**1.194**	**0.004**	**0.237**
Percent of Total for Chemical Group					
Total PCBs	0.00%	0.00%	0.00%	0.00%	0.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	100.00%	100.00%	100.00%	100.00%	100.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	100.00%	100.00%	100.00%	100.00%	100.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	NA	NA	NA	NA	NA

Table 5-65 Total Hazard Indices for the Local Resident (RME with Upper-bound Concentrations and Recent Mercury Data)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.097	0.043	0.086	0.004	0.237
Total	**0.097**	**0.043**	**0.086**	**0.004**	**0.237**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.097	0.043	0.086	0.004	0.237
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.097**	**0.043**	**0.086**	**0.004**	**0.237**
Percent of Total for Chemical Group					
Total PCBs	0.00%	0.00%	0.00%	0.00%	0.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	100.00%	100.00%	100.00%	100.00%	100.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	100.00%	100.00%	100.00%	100.00%	100.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	NA	NA	NA	NA	NA

Table 5-66 Total Cancer Risks for the Recreational Water User: Swimmer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.7E-07	2.7E-08	3.9E-08	5.5E-08	6.2E-09
Total Dioxins/Furans	3.9E-09	0.0E+00	6.0E-09	0.0E+00	0.0E+00
Total Pesticides	4.4E-10	5.7E-12	5.4E-11	5.2E-11	0.0E+00
Total Inorganics (Arsenic)	4.7E-08	4.6E-08	3.7E-08	1.5E-07	4.6E-08
Total	**2.2E-07**	**7.3E-08**	**8.1E-08**	**2.0E-07**	**5.2E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	2.6E-08	1.6E-08	2.1E-08	5.7E-08	4.1E-09
Inhalation of Indoor and Outdoor Air	1.1E-09	5.8E-10	7.5E-10	1.1E-09	3.2E-10
Ingestion/Dermal Contact with Sediment	1.9E-07	5.7E-08	6.0E-08	1.5E-07	4.8E-08
Total	**2.2E-07**	**7.3E-08**	**8.1E-08**	**2.0E-07**	**5.2E-08**
Percent of Total for Chemical Group					
Total PCBs	76.52%	37.29%	47.41%	27.17%	11.85%
Total Dioxins/Furans	1.78%	0.00%	7.35%	0.00%	0.00%
Total Pesticides	0.20%	0.01%	0.07%	0.03%	0.00%
Total Inorganics (Arsenic)	21.50%	62.71%	45.17%	72.81%	88.15%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	12.05%	21.96%	25.78%	27.92%	7.88%
Inhalation of Indoor and Outdoor Air	0.49%	0.79%	0.92%	0.55%	0.62%
Ingestion/Dermal Contact with Sediment	87.46%	77.26%	73.29%	71.53%	91.50%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.7E-07	2.7E-08	3.9E-08	5.5E-08	6.2E-09
Total PCBs using Aroclor Data	2.6E-07	1.4E-07	2.1E-07	1.1E-07	4.9E-09
Total PCBs using Congener Data	1.2E-07	1.0E-07	1.8E-07	1.1E-07	2.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	154.0%	517.8%	535.0%	205.6%	79.7%
Total PCBs using Congener Data	72.3%	378.5%	462.0%	191.1%	446.9%

Table 5-67 Total Hazard Indices for the Recreational Water User: Swimmer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.024	0.007	0.010	0.014	0.002
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.001	0.000
Mercury	0.035	0.001	0.012	0.000	0.002
Total	**0.059**	**0.008**	**0.022**	**0.015**	**0.004**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.011	0.006	0.009	0.011	0.002
Inhalation of Indoor and Outdoor Air	0.033	0.000	0.010	0.000	0.002
Ingestion/Dermal Contact with Sediment	0.015	0.002	0.003	0.005	0.001
Total	**0.059**	**0.008**	**0.022**	**0.015**	**0.004**
Percent of Total for Chemical Group					
Total PCBs	40.41%	89.95%	45.31%	93.64%	41.51%
Total Dioxins/Furans	0.05%	0.00%	0.18%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.44%	3.22%	0.92%	5.33%	6.15%
Mercury	59.10%	6.83%	53.59%	1.03%	52.34%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	18.79%	70.73%	38.92%	68.90%	36.46%
Inhalation of Indoor and Outdoor Air	55.14%	4.58%	45.88%	0.21%	48.63%
Ingestion/Dermal Contact with Sediment	26.07%	24.69%	15.20%	30.89%	14.91%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.024	0.007	0.010	0.014	0.002
Total PCBs using Aroclor Data	0.045	0.033	0.053	0.029	0.001
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	189.1%	455.7%	530.2%	202.7%	75.6%

Table 5-68 Total Cancer Risks for the Recreational Water User: Wader (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	4.2E-07	2.9E-08	4.2E-08	6.0E-08	4.4E-09
Total Dioxins/Furans	9.0E-09	0.0E+00	1.4E-08	0.0E+00	0.0E+00
Total Pesticides	1.7E-09	2.3E-11	2.2E-10	2.7E-11	0.0E+00
Total Inorganics (Arsenic)	7.1E-08	7.0E-08	5.6E-08	1.9E-07	7.0E-08
Total	**5.0E-07**	**9.9E-08**	**1.1E-07**	**2.5E-07**	**7.4E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	9.4E-10	5.8E-10	7.6E-10	7.4E-09	1.5E-10
Inhalation of Indoor and Outdoor Air	9.3E-11	5.1E-11	6.6E-11	9.9E-11	2.8E-11
Ingestion/Dermal Contact with Sediment	5.0E-07	9.8E-08	1.1E-07	2.4E-07	7.4E-08
Total	**5.0E-07**	**9.9E-08**	**1.1E-07**	**2.5E-07**	**7.4E-08**
Percent of Total for Chemical Group					
Total PCBs	83.71%	29.17%	37.73%	23.81%	5.90%
Total Dioxins/Furans	1.80%	0.00%	12.08%	0.00%	0.00%
Total Pesticides	0.34%	0.02%	0.19%	0.01%	0.00%
Total Inorganics (Arsenic)	14.15%	70.81%	49.99%	76.18%	94.10%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.19%	0.59%	0.67%	2.94%	0.20%
Inhalation of Indoor and Outdoor Air	0.02%	0.05%	0.06%	0.04%	0.04%
Ingestion/Dermal Contact with Sediment	99.79%	99.36%	99.27%	97.02%	99.76%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	4.2E-07	2.9E-08	4.2E-08	6.0E-08	4.4E-09
Total PCBs using Aroclor Data	5.8E-07	2.5E-07	3.1E-07	1.7E-07	7.3E-09
Total PCBs using Congener Data	1.2E-07	8.6E-08	2.7E-07	7.6E-08	2.0E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	139.4%	877.7%	734.1%	280.0%	166.4%
Total PCBs using Congener Data	28.2%	298.3%	650.4%	127.3%	461.6%

Table 5-69 Total Hazard Indices for the Recreational Water User: Wader (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.099	0.008	0.013	0.018	0.001
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.001	0.001	0.001	0.003	0.001
Mercury	0.011	0.001	0.005	0.000	0.001
Total	**0.111**	**0.010**	**0.019**	**0.022**	**0.003**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.002	0.001	0.002	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.009	0.000	0.003	0.000	0.001
Ingestion/Dermal Contact with Sediment	0.100	0.009	0.014	0.020	0.003
Total	**0.111**	**0.010**	**0.019**	**0.022**	**0.003**
Percent of Total for Chemical Group					
Total PCBs	88.92%	82.59%	66.78%	83.58%	41.35%
Total Dioxins/Furans	0.18%	0.00%	1.35%	0.00%	0.00%
Total Pesticides	0.02%	0.01%	0.02%	0.00%	0.00%
Arsenic	1.06%	11.84%	4.91%	14.76%	34.74%
Mercury	9.82%	5.57%	26.93%	1.66%	23.91%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	2.22%	6.31%	11.59%	5.75%	6.89%
Inhalation of Indoor and Outdoor Air	7.74%	0.97%	14.16%	0.04%	15.89%
Ingestion/Dermal Contact with Sediment	90.04%	92.72%	74.24%	94.21%	77.21%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.099	0.008	0.013	0.018	0.001
Total PCBs using Aroclor Data	0.173	0.097	0.140	0.075	0.003
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	174.4%	1187.8%	1102.5%	412.7%	250.2%

Table 5-70 Total Cancer Risks for the Marine Construction Worker (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.3E-06	8.7E-08	1.2E-07	1.8E-07	1.4E-08
Total Dioxins/Furans	3.4E-08	0.0E+00	5.0E-08	0.0E+00	0.0E+00
Total Pesticides	4.9E-09	6.6E-11	6.3E-10	7.6E-11	0.0E+00
Total Inorganics (Arsenic)	1.4E-07	1.3E-07	1.1E-07	3.7E-07	1.3E-07
Total	**1.5E-06**	**2.2E-07**	**2.8E-07**	**5.5E-07**	**1.5E-07**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	1.7E-09	1.1E-09	1.4E-09	1.7E-08	2.7E-10
Inhalation of Indoor and Outdoor Air	4.4E-09	2.4E-09	3.1E-09	4.7E-09	1.3E-09
Ingestion/Dermal Contact with Sediment	1.5E-06	2.2E-07	2.8E-07	5.2E-07	1.5E-07
Total	**1.5E-06**	**2.2E-07**	**2.8E-07**	**5.5E-07**	**1.5E-07**
Percent of Total for Chemical Group					
Total PCBs	88.12%	39.26%	43.95%	32.14%	9.23%
Total Dioxins/Furans	2.30%	0.00%	17.69%	0.00%	0.00%
Total Pesticides	0.33%	0.03%	0.22%	0.01%	0.00%
Total Inorganics (Arsenic)	9.25%	60.71%	38.13%	67.85%	90.77%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.12%	0.48%	0.49%	3.05%	0.18%
Inhalation of Indoor and Outdoor Air	0.30%	1.08%	1.11%	0.86%	0.91%
Ingestion/Dermal Contact with Sediment	99.58%	98.44%	98.40%	96.09%	98.91%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.3E-06	8.7E-08	1.2E-07	1.8E-07	1.4E-08
Total PCBs using Aroclor Data	1.7E-06	6.4E-07	7.0E-07	3.9E-07	1.6E-08
Total PCBs using Congener Data	3.6E-07	2.5E-07	7.6E-07	2.1E-07	5.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	129.0%	736.4%	567.9%	220.1%	115.4%
Total PCBs using Congener Data	28.1%	290.7%	613.9%	122.2%	427.4%

Table 5-71 Total Hazard Indices for the Marine Construction Worker (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.105	0.007	0.010	0.014	0.001
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.001	0.001	0.001	0.002	0.001
Mercury	0.166	0.002	0.054	0.001	0.010
Total	**0.272**	**0.011**	**0.065**	**0.018**	**0.012**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.002	0.000	0.002	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.163	0.002	0.051	0.000	0.010
Ingestion/Dermal Contact with Sediment	0.107	0.008	0.012	0.016	0.002
Total	**0.272**	**0.011**	**0.065**	**0.018**	**0.012**
Percent of Total for Chemical Group					
Total PCBs	38.70%	68.53%	15.77%	82.44%	8.76%
Total Dioxins/Furans	0.11%	0.00%	0.56%	0.00%	0.00%
Total Pesticides	0.01%	0.01%	0.01%	0.00%	0.00%
Arsenic	0.33%	8.52%	1.10%	14.03%	7.21%
Mercury	60.85%	22.94%	82.55%	3.53%	84.02%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.77%	4.36%	2.94%	5.30%	1.49%
Inhalation of Indoor and Outdoor Air	59.94%	17.29%	78.44%	0.90%	81.39%
Ingestion/Dermal Contact with Sediment	39.29%	78.35%	18.63%	93.80%	17.12%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.105	0.007	0.010	0.014	0.001
Total PCBs using Aroclor Data	0.135	0.052	0.057	0.031	0.001
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	128.5%	719.0%	555.1%	214.8%	117.4%

Table 5-72 Cancer Risks for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to De Pere Reach	De Pere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
RME with Average Concentrations	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
CTE with Average Concentrations	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
High-intake Fish Consumer					
RME with Upper-bound Concentrations	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
RME with Average Concentrations	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
CTE with Average Concentrations	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Hunter					
RME with Upper-bound Concentrations	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
RME with Average Concentrations	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
CTE with Average Concentrations	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Drinking Water User					
RME with Upper-bound Concentrations	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.2E-08
Local Resident					
RME with Upper-bound Concentrations	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	2.2E-07	7.3E-08	8.1E-08	2.0E-07	5.2E-08
Recreational Water User—Wader					
RME with Upper-bound Concentrations	5.0E-07	9.9E-08	1.1E-07	2.5E-07	7.4E-08
Marine Construction Worker					
RME with Upper-bound Concentrations	1.5E-06	2.2E-07	2.8E-07	5.5E-07	1.5E-07

Table 5-73 Hazard Indices for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to DePere Reach	DePere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	76.2	107.1	17.9	59.8	55.9
RME with Average Concentrations	59.1	83.9	14.6	52.8	53.2
CTE with Average Concentrations	15.0	21.3	3.7	13.4	13.5
High-intake Fish Consumer					
RME with Upper-bound Concentrations	104.3	146.8	24.5	82.0	86.6
RME with Average Concentrations	80.9	114.9	20.0	72.4	72.8
CTE with Average Concentrations	21.2	30.1	5.2	18.9	19.0
Hunter					
RME with Upper-bound Concentrations	1.7	2.0	3.1	2.0	2.1
RME with Average Concentrations	0.9	1.3	1.1	0.6	0.8
CTE with Average Concentrations	0.5	0.7	0.6	0.3	0.4
Drinking Water User					
RME with Upper-bound Concentrations	3.56	0.10	3.22	0.33	0.19
RME with Upper-bound Concentrations and Recent Mercury Data	0.17	0.10	0.16	0.33	0.19
Local Resident					
RME with Upper-bound Concentrations	3.823	0.043	1.194	0.004	0.237
RME with Upper-bound Concentrations and Recent Mercury Data	0.097	0.043	0.086	0.004	0.237
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	0.059	0.008	0.022	0.015	0.004
Recreational Water User—Wader					
RME with Upper-bound Concentrations	0.111	0.010	0.019	0.022	0.003
Marine Construction Worker					
RME with Upper-bound Concentrations	0.272	0.011	0.065	0.018	0.012

Table 5-74 Summary of Lead Data in Surface Sediment Samples

Reach of Lower Fox River	Frequency of Detection	Range of Detected Concentrations (mg/kg)
Little Lake Butte des Morts	27/27	3.8–522
Appleton to Little Rapids	15/15	5.17–280
Little Rapids to De Pere	20/20	6.15–1,400
De Pere to Green Bay	95/95	4.44–350
Reference/Background	10/10	14–39

Table 5-75 Fish Species with Fillet and Skin Tissue Samples for Total PCBs

Black Bullhead
Black Crappie
Bluegill
Brook Trout
Brown Bullhead
Brown Trout
Burbot
Carp
Chinook Salmon
Cisco/Lake Herring
Freshwater Drum
Lake Trout
Lake Whitefish
Largemouth Bass
Northern Pike
Pumpkinseed
Rainbow Smelt
Rock Bass
Sauger
Smallmouth Bass
Splake
Walleye
White Bass
White Perch
White Sucker
Yellow Perch

Table 5-76 Summary of Total PCB Concentrations in Fish Tissue Samples from the Lower Fox River

Sample Type	Number of Samples	Number of Detects	Minimum Detected Concentration (µg/kg)	Median (µg/kg)	Average (µg/kg)	95th Percentile (µg/kg)	Maximum Detected Concentration (µg/kg)	Standard Deviation (µg/kg)
Little Lake Butte des Morts Reach								
All Fish Samples	286	265	46	650	2,817	13,900	39,000	5,881
All Fish Samples in 1990s	126	126	46	310	960	4,550	9,300	1,630
All Carp Samples	76	76	140	4,200	8,074	30,000	39,000	9,321
All Carp Samples in 1990s	30	30	354	3,185	3,173	6,941	9,300	2,158
All Perch Samples	34	24	75	240	406	989	1,400	364
All Perch Samples in 1990s	6	6	75	104	152	295	320	98
All Walleye Samples	71	62	55	380	649	2,100	5,200	846
All Walleye Samples in 1990s	39	34	55	270	272	523	940	190
All White Bass Samples	26	25	70	205	291	633	2,200	411
All White Bass Samples in 1990s	20	20	70	185	206	303	740	144
Appleton to Little Rapids Reach								
All Fish Samples	113	111	69	1,400	3,979	16,400	57,000	7,683
All Fish Samples in 1990s	22	22	69	670	910	2,260	4,000	863
All Carp Samples	24	24	750	6,850	12,035	36,200	57,000	13,522
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples	2	1	440	270	270	423	440	240
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples	30	30	69	1,095	2,197	6,785	14,000	2,902
All Walleye Samples in 1990s	5	5	69	140	300	632	660	271
All White Bass Samples	8	8	530	880	1,335	3,275	3,800	1,149
All White Bass Samples in 1990s	7	7	530	760	983	1,940	2,300	620
Little Rapids to De Pere Reach								
All Fish Samples	101	92	46	410	603	1,300	4,000	708
All Fish Samples in 1990s	101	92	46	410	603	1,300	4,000	708
All Carp Samples	2	2	720	1,010	1,010	1,271	1,300	410
All Carp Samples in 1990s	2	2	720	1,010	1,010	1,271	1,300	410
All Perch Samples	6	6	46	565	528	905	920	347
All Perch Samples in 1990s	6	6	46	565	528	905	920	347
All Walleye Samples	48	47	110	370	541	1,165	2,800	457
All Walleye Samples in 1990s	48	47	110	370	541	1,165	2,800	457
All White Bass Samples	14	14	180	670	852	2,170	3,600	886
All White Bass Samples in 1990s	14	14	180	670	852	2,170	3,600	886
De Pere to Green Bay Reach								
All Fish Samples	520	512	45	1,420	2,440	8,805	50,000	3,681
All Fish Samples in 1990s	292	287	45	1,100	1,344	3,529	4,800	1,020
All Carp Samples	40	40	1,200	7,000	9,044	17,754	50,000	8,895
All Carp Samples in 1990s	3	3	2,300	3,000	3,023	3,691	3,768	734
All Perch Samples	43	40	45	730	1,116	2,970	5,300	1,199
All Perch Samples in 1990s	31	28	45	220	1,052	2,850	3,100	1,149
All Walleye Samples	155	154	110	1,380	1,533	3,490	8,100	1,131
All Walleye Samples in 1990s	125	124	110	1,285	1,347	2,868	4,600	833
All White Bass Samples	64	64	370	2,400	2,823	6,395	8,400	1,688
All White Bass Samples in 1990s	46	46	370	2,300	2,295	4,200	4,800	1,085

Notes:

Perch data include white perch and yellow perch samples.

The average is used in the risk calculations. Other statistics are provided to supply information on the data sets.

Table 5-77 Calculation of PCB Concentration in Carp Fillet Using Fillet-to-Whole Body Ratio

Reach/Zone	Measured Total PCB Data				Calculated Fillet Concentration [3] (mg/kg)
	Fillet Samples [1]		Whole Body Samples [2]		
	No. of Samples	Mean (mg/kg)	No. of Samples	Mean (mg/kg)	
Little Lake Butte des Morts	30	3.173	30	1.992	1.056
Appleton to Little Rapids	NA	NA	12	2.581	1.368
Little Rapids to De Pere	2	1.010	20	3.919	2.077
De Pere to Green Bay	3	3.023	115	6.637	3.518
Green Bay Zone 3A	1	0.126	NA	NA	NA
Green Bay Zone 3B	NA	NA	NA	NA	NA
Green Bay Zone 4	1	2.840	NA	NA	NA

Ratio of Fillet to Whole Body PCB Concentrations = 0.53

Notes:

[1] Includes samples from 1990 on.

[2] Includes samples from 1989 on.

[3] Applies the calculated ratio to the measured whole body concentration.

NA - Not Available

Table 5-78 Summary of Total PCB Concentrations in Fish Tissue Samples from Green Bay

Sample Type	Number of Samples	Number of Detects	Minimum Detected Concentration (µg/kg)	Median (µg/kg)	Average (µg/kg)	95th Percentile (µg/kg)	Maximum Detected Concentration (µg/kg)	Standard Deviation (µg/kg)
Green Bay Zone 3A								
All Fish Samples	295	292	88	1,800	2,057	4,800	11,697	1,513
All Fish Samples in 1990s	101	100	126	950	1,357	3,600	5,500	1,146
All Carp Samples	16	16	88	3,755	3,918	8,774	11,697	2,983
All Carp Samples in 1990s	1	1	126	126	126	126	126	NA
All Perch Samples	20	20	220	1,250	1,869	4,835	5,500	1,511
All Perch Samples in 1990s	19	19	370	1,300	1,955	4,870	5,500	1,501
All Walleye Samples	15	15	157	1,020	1,671	4,897	5,520	1,583
All Walleye Samples from 1989 on	5	5	560	1,072	1,134	1,741	1,820	502
All White Bass Samples	NA	NA	NA	NA	NA	NA	NA	NA
All White Bass Samples In 1990s	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B								
All Fish Samples	103	102	240	2,200	3,551	12,120	24,000	4,012
All Fish Samples in 1990s	9	9	800	970	1,039	1,344	1,370	213
All Carp Samples	16	16	2,100	7,800	8,569	19,275	24,000	6,013
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples	12	12	240	825	817	1,335	1,500	366
All Perch Samples in 1990s	5	5	800	970	1,000	1,180	1,200	155
All Walleye Samples	23	23	500	2,300	2,510	5,060	8,100	1,958
All Walleye Samples from 1989 on	4	4	822	1,080	1,088	1,360	1,370	289
All White Bass Samples	NA	NA	NA	NA	NA	NA	NA	NA
All White Bass Samples In 1990s	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4								
All Fish Samples	188	185	26	835	1,452	3,637	38,000	3,059
All Fish Samples in 1990s	115	115	34	622	951	2,870	3,900	859
All Carp Samples	11	11	65	1,240	2,390	8,151	8,640	2,988
All Carp Samples in 1990s	1	1	2,840	2,840	2,840	2,840	2,840	NA
All Perch Samples	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples	30	30	132	456	678	1,486	3,520	690
All Walleye Samples from 1989 on	30	30	132	456	678	1,486	3,520	690
All White Bass Samples	NA	NA	NA	NA	NA	NA	NA	NA
All White Bass Samples In 1990s	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

All fish samples includes walleye data from 1989.
Perch data include white perch and yellow perch samples.
The average is used in the risk calculations. Other statistics are provided to supply information on the data sets.

Table 5-79 PCB Concentrations in Skin-on Fillet Fish Samples from Lake Winnebago

Fish Specie	Sample Date	Concentration (µg/kg)
White Bass	07/31/92	< 40
Walleye	07/31/92	< 40
Walleye	07/31/92	< 40
Walleye	07/31/92	42
White Bass	08/04/92	130
White Bass	08/04/92	140
Northern Pike	08/11/92	71
Average		**63.3**

Table 5-80 Intake Assumptions and Toxicological Parameters for the Recreational Angler

Parameter	1989 Michigan Study RME (West *et al.*, 1989)	1989 Michigan Study CTE (West *et al.*, 1989)	1993 Michigan Study RME (West *et al.*, 1993)	1993 Michigan Study CTE (West *et al.*, 1993)	Average of Michigan Studies RME (West *et al.*, 1989, 1993)	Average of Michigan Studies CTE (West *et al.*, 1989, 1993)	1989 Wisconsin Study RME (Fiore *et al.*, 1989)	1989 Wisconsin Study CTE (Fiore *et al.*, 1989)
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	39	12	78	17	59	15	227	227
EF (days/year or meals/year)	365	365	365	365	365	365	59	18
Basis: Annualized IR								
IR (g/day)	39	12	78	17	59	15	37	11
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	63	19	125	27	94	23	59	18
Other Intake Parameters								
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	50	30	50	30	50	30	50	30
BW (kg)	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8
ATc (days)	27,375	27,375	27,375	27,375	27,375	27,375	27,375	27,375
ATnc (days)	18,250	10,950	18,250	10,950	18,250	10,950	18,250	10,950
Cancer Slope Factor								
CSF $(mg/kg\text{-}day)^{-1}$	2	2	2	2	2	2	2	2
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Cancer Intake Factor								
IntFacC (kg-fish/kg-BW-day)	1.8E-04	3.3E-05	3.6E-04	4.7E-05	2.7E-04	4.0E-05	1.7E-04	3.1E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	2.7E-04	8.4E-05	5.4E-04	1.2E-04	4.1E-04	1.0E-04	2.6E-04	7.8E-05

Table 5-81 Intake Assumptions and Toxicological Parameters for the High-intake Fish Consumer

Parameter	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	110	43	227	227	227	227	227	227
EF (days/year or meals/year)	365	365	89	27	130	34	52	12
Basis: Annualized IR								
IR (g/day)	110	43	55	17	81	21	32	7
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	177	69	89	27	130	34	52	12
Other Intake Parameters								
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	50	30	50	30	50	30	50	30
BW (kg)	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8
ATc (days)	27,375	27,375	27,375	27,375	27,375	27,375	27,375	27,375
ATnc (days)	18,250	10,950	18,250	10,950	18,250	10,950	18,250	10,950
Cancer Slope Factor								
CSF $(mg/kg\text{-}day)^{-1}$	2	2	2	2	2	2	2	2
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Cancer Intake Factor								
IntFacC (kg-fish/kg-BW-day)	5.1E-04	1.2E-04	2.6E-04	4.7E-05	3.8E-04	5.9E-05	1.5E-04	2.1E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	7.7E-04	3.0E-04	3.9E-04	1.2E-04	5.6E-04	1.5E-04	2.3E-04	5.2E-05

Table 5-82 Cancer Risks by Lower Fox River Reach for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	1989 Michigan Study CTE	1993 Michigan Study (West *et al.*, 1993) RME	1993 Michigan Study CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	Average of Michigan Studies CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	1989 Wisconsin Study CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*3.5E-04*	*6.4E-05*	*7.0E-04*	*9.1E-05*	*5.2E-04*	*7.8E-05*	*3.3E-04*	*6.0E-05*
All Carp Samples in 1990s	3.173	1.1E-03	2.1E-04	2.3E-03	3.0E-04	1.7E-03	2.6E-04	1.1E-03	2.0E-04
All Perch Samples in 1990s	0.152	5.5E-05	1.0E-05	1.1E-04	1.4E-05	8.2E-05	1.2E-05	5.2E-05	9.5E-06
All Walleye Samples in 1990s	0.272	9.9E-05	1.8E-05	2.0E-04	2.6E-05	1.5E-04	2.2E-05	9.3E-05	1.7E-05
All White Bass Samples in 1990s	0.206	7.4E-05	1.4E-05	1.5E-04	1.9E-05	1.1E-04	1.7E-05	7.0E-05	1.3E-05
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*3.3E-04*	*6.1E-05*	*6.6E-04*	*8.6E-05*	*4.9E-04*	*7.4E-05*	*3.1E-04*	*5.7E-05*
All Carp Samples in 1990s	1.368	5.0E-04	9.1E-05	9.9E-04	1.3E-04	7.4E-04	1.1E-04	4.7E-04	8.5E-05
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	1.1E-04	2.0E-05	2.2E-04	2.8E-05	1.6E-04	2.4E-05	1.0E-04	1.9E-05
All White Bass Samples in 1990s	0.983	3.6E-04	6.6E-05	7.1E-04	9.3E-05	5.3E-04	7.9E-05	3.3E-04	6.1E-05
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*2.2E-04*	*4.0E-05*	*4.4E-04*	*5.7E-05*	*3.3E-04*	*4.9E-05*	*2.1E-04*	*3.8E-05*
All Carp Samples in 1990s	1.010	3.7E-04	6.8E-05	7.3E-04	9.6E-05	5.5E-04	8.2E-05	3.4E-04	6.3E-05
All Perch Samples in 1990s	0.528	1.9E-04	3.5E-05	3.8E-04	5.0E-05	2.9E-04	4.3E-05	1.8E-04	3.3E-05
All Walleye Samples in 1990s	0.541	2.0E-04	3.6E-05	3.9E-04	5.1E-05	2.9E-04	4.4E-05	1.8E-04	3.4E-05
All White Bass Samples in 1990s	0.852	3.1E-04	5.7E-05	6.2E-04	8.1E-05	4.6E-04	6.9E-05	2.9E-04	5.3E-05
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*4.9E-04*	*9.0E-05*	*9.7E-04*	*1.3E-04*	*7.3E-04*	*1.1E-04*	*4.6E-04*	*8.4E-05*
All Carp Samples in 1990s	3.023	1.1E-03	2.0E-04	2.2E-03	2.9E-04	1.6E-03	2.4E-04	1.0E-03	1.9E-04
All Perch Samples in 1990s	1.052	3.8E-04	7.0E-05	7.6E-04	1.0E-04	5.7E-04	8.5E-05	3.6E-04	6.6E-05
All Walleye Samples in 1990s	1.347	4.9E-04	9.0E-05	9.8E-04	1.3E-04	7.3E-04	1.1E-04	4.6E-04	8.4E-05
All White Bass Samples in 1990s	2.295	8.3E-04	1.5E-04	1.7E-03	2.2E-04	1.2E-03	1.9E-04	7.8E-04	1.4E-04
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.3E-05	4.2E-06	4.6E-05	6.0E-06	3.4E-05	5.1E-06	2.1E-05	3.9E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.
The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio

Table 5-83 Cancer Risks by Green Bay Zone for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	1989 Michigan Study CTE	1993 Michigan Study (West *et al.*, 1993) RME	1993 Michigan Study CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	Average of Michigan Studies CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	1989 Wisconsin Study CTE
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*4.9E-04*	*9.1E-05*	*9.8E-04*	*1.3E-04*	*7.4E-04*	*1.1E-04*	*4.6E-04*	*8.5E-05*
All Carp Samples in 1990s	0.126	4.6E-05	8.4E-06	9.1E-05	1.2E-05	6.8E-05	1.0E-05	4.3E-05	7.9E-06
All Perch Samples in 1990s	1.955	7.1E-04	1.3E-04	1.4E-03	1.9E-04	1.1E-03	1.6E-04	6.7E-04	1.2E-04
All Walleye Samples from 1989 on	1.134	4.1E-04	7.6E-05	8.2E-04	1.1E-04	6.2E-04	9.2E-05	3.9E-04	7.1E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*3.8E-04*	*6.9E-05*	*7.5E-04*	*9.8E-05*	*5.6E-04*	*8.4E-05*	*3.5E-04*	*6.5E-05*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	3.6E-04	6.7E-05	7.2E-04	9.5E-05	5.4E-04	8.1E-05	3.4E-04	6.2E-05
All Walleye Samples from 1989 on	1.088	3.9E-04	7.3E-05	7.9E-04	1.0E-04	5.9E-04	8.8E-05	3.7E-04	6.8E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*3.4E-04*	*6.4E-05*	*6.9E-04*	*9.0E-05*	*5.2E-04*	*7.7E-05*	*3.2E-04*	*5.9E-05*
All Carp Samples in 1990s	2.840	1.0E-03	1.9E-04	2.1E-03	2.7E-04	1.5E-03	2.3E-04	9.7E-04	1.8E-04
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	2.5E-04	4.5E-05	4.9E-04	6.4E-05	3.7E-04	5.5E-05	2.3E-04	4.2E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in 1990s	0.063	2.3E-05	4.2E-06	4.6E-05	6.0E-06	3.4E-05	5.1E-06	2.1E-05	3.9E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-84 Hazard Indices by Lower Fox River Reach for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*13.0*	*4.0*	*26.1*	*5.7*	*19.6*	*4.8*	*12.3*	*3.7*
All Carp Samples in 1990s	3.173	43.1	13.3	86.2	18.8	64.6	16.0	40.5	12.4
All Perch Samples in 1990s	0.152	2.1	0.6	4.1	0.9	3.1	0.8	1.9	0.6
All Walleye Samples in 1990s	0.272	3.7	1.1	7.4	1.6	5.5	1.4	3.5	1.1
All White Bass Samples in 1990s	0.206	2.8	0.9	5.6	1.2	4.2	1.0	2.6	0.8
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*12.4*	*3.8*	*24.7*	*5.4*	*18.5*	*4.6*	*11.6*	*3.5*
All Carp Samples in 1990s	1.368	18.6	5.7	37.2	8.1	27.9	6.9	17.5	5.3
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	4.1	1.3	8.1	1.8	6.1	1.5	3.8	1.2
All White Bass Samples in 1990s	0.983	13.3	4.1	26.7	5.8	20.0	5.0	12.6	3.8
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*8.2*	*2.5*	*16.4*	*3.6*	*12.3*	*3.0*	*7.7*	*2.4*
All Carp Samples in 1990s	1.010	13.7	4.2	27.4	6.0	20.6	5.1	12.9	3.9
All Perch Samples in 1990s	0.528	7.2	2.2	14.3	3.1	10.7	2.7	6.7	2.1
All Walleye Samples in 1990s	0.541	7.3	2.3	14.7	3.2	11.0	2.7	6.9	2.1
All White Bass Samples in 1990s	0.852	11.6	3.6	23.1	5.0	17.4	4.3	10.9	3.3
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*18.3*	*5.6*	*36.5*	*8.0*	*27.4*	*6.8*	*17.2*	*5.2*
All Carp Samples in 1990s	3.023	41.0	12.6	82.1	17.9	61.6	15.3	38.6	11.8
All Perch Samples in 1990s	1.052	14.3	4.4	28.6	6.2	21.4	5.3	13.4	4.1
All Walleye Samples in 1990s	1.347	18.3	5.6	36.6	8.0	27.4	6.8	17.2	5.3
All White Bass Samples in 1990s	2.295	31.2	9.6	62.3	13.6	46.7	11.6	29.3	8.9
Lake Winnebago									
All Fish Samples in the 1990s	0.063	0.9	0.3	1.7	0.4	1.3	0.3	0.8	0.2

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-85 Hazard Indices by Green Bay Zone for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*18.4*	*5.7*	*36.9*	*8.0*	*27.7*	*6.9*	*17.3*	*5.3*
All Carp Samples in 1990s	0.126	1.7	0.5	3.4	0.7	2.6	0.6	1.6	0.5
All Perch Samples in 1990s	1.955	26.6	8.2	53.1	11.6	39.8	9.9	25.0	7.6
All Walleye Samples from 1989 on	1.134	15.4	4.7	30.8	6.7	23.1	5.7	14.5	4.4
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*14.1*	*4.3*	*28.2*	*6.2*	*21.2*	*5.2*	*13.3*	*4.1*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	13.6	4.2	27.2	5.9	20.4	5.0	12.8	3.9
All Walleye Samples from 1989 on	1.088	14.8	4.5	29.5	6.4	22.2	5.5	13.9	4.2
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*12.9*	*4.0*	*25.8*	*5.6*	*19.4*	*4.8*	*12.1*	*3.7*
All Carp Samples in 1990s	2.840	38.6	11.9	77.1	16.8	57.8	14.3	36.3	11.1
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	9.2	2.8	18.4	4.0	13.8	3.4	8.7	2.6
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in the 1990s	0.063	0.9	0.3	1.7	0.4	1.3	0.3	0.8	0.2

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-86 Cancer Risks by Lower Fox River Reach for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*9.8E-04*	*2.3E-04*	*4.9E-04*	*9.0E-05*	*7.2E-04*	*1.1E-04*	*2.9E-04*	*4.0E-05*
All Carp Samples in 1990s	3.173	3.2E-03	7.6E-04	1.6E-03	3.0E-04	2.4E-03	3.7E-04	9.5E-04	1.3E-04
All Perch Samples in 1990s	0.152	1.5E-04	3.6E-05	7.8E-05	1.4E-05	1.1E-04	1.8E-05	4.6E-05	6.3E-06
All Walleye Samples in 1990s	0.272	2.8E-04	6.5E-05	1.4E-04	2.5E-05	2.0E-04	3.2E-05	8.2E-05	1.1E-05
All White Bass Samples in 1990s	0.206	2.1E-04	4.9E-05	1.1E-04	1.9E-05	1.5E-04	2.4E-05	6.2E-05	8.6E-06
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*9.3E-04*	*2.2E-04*	*4.7E-04*	*8.5E-05*	*6.8E-04*	*1.1E-04*	*2.7E-04*	*3.8E-05*
All Carp Samples in 1990s	1.368	1.4E-03	3.3E-04	7.0E-04	1.3E-04	1.0E-03	1.6E-04	4.1E-04	5.7E-05
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	3.1E-04	7.2E-05	1.5E-04	2.8E-05	2.3E-04	3.5E-05	9.0E-05	1.2E-05
All White Bass Samples in 1990s	0.983	1.0E-03	2.4E-04	5.1E-04	9.2E-05	7.4E-04	1.2E-04	3.0E-04	4.1E-05
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*6.2E-04*	*1.4E-04*	*3.1E-04*	*5.6E-05*	*4.5E-04*	*7.1E-05*	*1.8E-04*	*2.5E-05*
All Carp Samples in 1990s	1.010	1.0E-03	2.4E-04	5.2E-04	9.4E-05	7.6E-04	1.2E-04	3.0E-04	4.2E-05
All Perch Samples in 1990s	0.528	5.4E-04	1.3E-04	2.7E-04	4.9E-05	4.0E-04	6.2E-05	1.6E-04	2.2E-05
All Walleye Samples in 1990s	0.541	5.5E-04	1.3E-04	2.8E-04	5.1E-05	4.1E-04	6.4E-05	1.6E-04	2.2E-05
All White Bass Samples in 1990s	0.852	8.7E-04	2.0E-04	4.4E-04	8.0E-05	6.4E-04	1.0E-04	2.6E-04	3.5E-05
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*1.4E-03*	*3.2E-04*	*6.9E-04*	*1.3E-04*	*1.0E-03*	*1.6E-04*	*4.0E-04*	*5.6E-05*
All Carp Samples in 1990s	3.023	3.1E-03	7.2E-04	1.6E-03	2.8E-04	2.3E-03	3.6E-04	9.1E-04	1.3E-04
All Perch Samples in 1990s	1.052	1.1E-03	2.5E-04	5.4E-04	9.8E-05	7.9E-04	1.2E-04	3.2E-04	4.4E-05
All Walleye Samples in 1990s	1.347	1.4E-03	3.2E-04	6.9E-04	1.3E-04	1.0E-03	1.6E-04	4.0E-04	5.6E-05
All White Bass Samples in 1990s	2.295	2.3E-03	5.5E-04	1.2E-03	2.1E-04	1.7E-03	2.7E-04	6.9E-04	9.5E-05
Lake Winnebago									
All Fish Samples in the 1990s	0.063	6.4E-05	1.5E-05	3.2E-05	5.9E-06	4.7E-05	7.4E-06	1.9E-05	2.6E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.
The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-87 Cancer Risks by Green Bay Zone for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority (West *et al.*, 1993) RME	CTE	Native American (Peterson *et al.*, 1994 and Fiore *et al.*, 1989) RME	CTE	Hmong (Hutchison and Kraft, 1994) RME	CTE	Hmong/Laotian (Hutchison, 1999) RME	CTE
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*1.4E-03*	*3.3E-04*	*7.0E-04*	*1.3E-04*	*1.0E-03*	*1.6E-04*	*4.1E-04*	*5.6E-05*
All Carp Samples in 1990s	0.126	1.3E-04	3.0E-05	6.5E-05	1.2E-05	9.5E-05	1.5E-05	3.8E-05	5.2E-06
All Perch Samples in 1990s	1.955	2.0E-03	4.7E-04	1.0E-03	1.8E-04	1.5E-03	2.3E-04	5.9E-04	8.1E-05
All Walleye Samples from 1989 on	1.134	1.2E-03	2.7E-04	5.8E-04	1.1E-04	8.5E-04	1.3E-04	3.4E-04	4.7E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*1.1E-03*	*2.5E-04*	*5.3E-04*	*9.7E-05*	*7.8E-04*	*1.2E-04*	*3.1E-04*	*4.3E-05*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	1.0E-03	2.4E-04	5.1E-04	9.4E-05	7.5E-04	1.2E-04	3.0E-04	4.2E-05
All Walleye Samples from 1989 on	1.088	1.1E-03	2.6E-04	5.6E-04	1.0E-04	8.2E-04	1.3E-04	3.3E-04	4.5E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*9.7E-04*	*2.3E-04*	*4.9E-04*	*8.9E-05*	*7.1E-04*	*1.1E-04*	*2.9E-04*	*4.0E-05*
All Carp Samples in 1990s	2.840	2.9E-03	6.8E-04	1.5E-03	2.7E-04	2.1E-03	3.3E-04	8.5E-04	1.2E-04
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	6.9E-04	1.6E-04	3.5E-04	6.3E-05	5.1E-04	8.0E-05	2.0E-04	2.8E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in the 1990s	0.063	6.4E-05	1.5E-05	3.2E-05	5.9E-06	4.7E-05	7.4E-06	1.9E-05	2.6E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-88 Hazard Indices by Lower Fox River Reach for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority (West *et al.*, 1993)		Native American (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)		Hmong (Hutchison and Kraft, 1994)		Hmong/Laotian (Hutchison, 1999)	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*36.8*	*14.4*	*18.5*	*5.6*	*27.0*	*7.1*	*10.8*	*2.5*
All Carp Samples in 1990s	3.173	121.5	47.5	61.2	18.6	89.3	23.4	35.7	8.2
All Perch Samples in 1990s	0.152	5.8	2.3	2.9	0.9	4.3	1.1	1.7	0.4
All Walleye Samples in 1990s	0.272	10.4	4.1	5.2	1.6	7.7	2.0	3.1	0.7
All White Bass Samples in 1990s	0.206	7.9	3.1	4.0	1.2	5.8	1.5	2.3	0.5
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*34.9*	*13.6*	*17.5*	*5.3*	*25.6*	*6.7*	*10.3*	*2.4*
All Carp Samples in 1990s	1.368	52.4	20.5	26.4	8.0	38.5	10.1	15.4	3.6
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	11.5	4.5	5.8	1.8	8.4	2.2	3.4	0.8
All White Bass Samples in 1990s	0.983	37.6	14.7	18.9	5.7	27.7	7.2	11.1	2.6
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*23.1*	*9.0*	*11.6*	*3.5*	*17.0*	*4.4*	*6.8*	*1.6*
All Carp Samples in 1990s	1.010	38.7	15.1	19.5	5.9	28.4	7.4	11.4	2.6
All Perch Samples in 1990s	0.528	20.2	7.9	10.2	3.1	14.9	3.9	5.9	1.4
All Walleye Samples in 1990s	0.541	20.7	8.1	10.4	3.2	15.2	4.0	6.1	1.4
All White Bass Samples in 1990s	0.852	32.6	12.8	16.4	5.0	24.0	6.3	9.6	2.2
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*51.5*	*20.1*	*25.9*	*7.9*	*37.8*	*9.9*	*15.1*	*3.5*
All Carp Samples in 1990s	3.023	115.8	45.3	58.3	17.7	85.1	22.3	34.0	7.9
All Perch Samples in 1990s	1.052	40.3	15.8	20.3	6.2	29.6	7.7	11.8	2.7
All Walleye Samples in 1990s	1.347	51.6	20.2	26.0	7.9	37.9	9.9	15.2	3.5
All White Bass Samples in 1990s	2.295	87.9	34.4	44.2	13.4	64.6	16.9	25.8	6.0
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.4	0.9	1.2	0.4	1.8	0.5	0.7	0.2

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.
The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio

Table 5-89 Hazard Indices by Green Bay Zone for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*5.2E+01*	*2.0E+01*	*2.6E+01*	*7.9E+00*	*3.8E+01*	*1.0E+01*	*1.5E+01*	*3.5E+00*
All Carp Samples in 1990s	0.126	4.8E+00	1.9E+00	2.4E+00	7.4E-01	3.5E+00	9.3E-01	1.4E+00	3.3E-01
All Perch Samples in 1990s	1.955	7.5E+01	2.9E+01	3.8E+01	1.1E+01	5.5E+01	1.4E+01	2.2E+01	5.1E+00
All Walleye Samples from 1989 on	1.134	4.3E+01	1.7E+01	2.2E+01	6.6E+00	3.2E+01	8.3E+00	1.3E+01	2.9E+00
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*4.0E+01*	*1.6E+01*	*2.0E+01*	*6.1E+00*	*2.9E+01*	*7.7E+00*	*1.2E+01*	*2.7E+00*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	3.8E+01	1.5E+01	1.9E+01	5.8E+00	2.8E+01	7.4E+00	1.1E+01	2.6E+00
All Walleye Samples from 1989 on	1.088	4.2E+01	1.6E+01	2.1E+01	6.4E+00	3.1E+01	8.0E+00	1.2E+01	2.8E+00
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*3.6E+01*	*1.4E+01*	*1.8E+01*	*5.6E+00*	*2.7E+01*	*7.0E+00*	*1.1E+01*	*2.5E+00*
All Carp Samples in 1990s	2.840	1.1E+02	4.3E+01	5.5E+01	1.7E+01	8.0E+01	2.1E+01	3.2E+01	7.4E+00
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	2.6E+01	1.0E+01	1.3E+01	4.0E+00	1.9E+01	5.0E+00	7.6E+00	1.8E+00
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.4E+00	9.4E-01	1.2E+00	3.7E-01	1.8E+00	4.6E-01	7.1E-01	1.6E-01

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-90 Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Parameter	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Intake Parameters				
IR and EF Basis: Original Study				
IR (g/day or g/meal)	227	227	227	227
EF (days/year or meals/year)	225	52	12	6
Basis: Annualized IR				
IR (g/day)	140	32	7	4
EF (days/year)	365	365	365	365
Basis: Normalized Meals per Year				
IR (g/meal)	227	227	227	227
EF (meals/year)	225	52	12	6
Other Intake Parameters				
RF (mg/mg)	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	75	75	75	75
BW (kg)	70	70	70	70
ATc (days)	27,375	27,375	27,375	27,375
ATnc (days)	27,375	27,375	27,375	27,375
Cancer Slope Factor				
CSF $(mg/kg\text{-}day)^{-1}$	2	2	2	2
Reference Dose				
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Cancer Intake Factor				
IntFacC (kg-fish/kg-BW-day)	1.0E-03	2.3E-04	5.3E-05	2.7E-05
Noncancer Intake Factor				
IntFacNc (kg-fish/kg-BW-day)	1.0E-03	2.3E-04	5.3E-05	2.7E-05

Table 5-91 Cancer Risks by Lower Fox River Reach Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts					
All Fish Samples in 1990s	*0.960*	*1.9E-03*	*4.4E-04*	*1.0E-04*	*5.1E-05*
All Carp Samples in 1990s	3.173	6.3E-03	1.5E-03	3.4E-04	1.7E-04
All Perch Samples in 1990s	0.152	3.0E-04	7.0E-05	1.6E-05	8.1E-06
All Walleye Samples in 1990s	0.272	5.4E-04	1.3E-04	2.9E-05	1.5E-05
All White Bass Samples in 1990s	0.206	4.1E-04	9.5E-05	2.2E-05	1.1E-05
Appleton to Little Rapids					
All Fish Samples in 1990s	*0.910*	*1.8E-03*	*4.2E-04*	*9.7E-05*	*4.9E-05*
All Carp Samples in 1990s	1.368	2.7E-03	6.3E-04	1.5E-04	7.3E-05
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	6.0E-04	1.4E-04	3.2E-05	1.6E-05
All White Bass Samples in 1990s	0.983	2.0E-03	4.5E-04	1.0E-04	5.2E-05
Little Rapids to De Pere					
All Fish Samples in 1990s	*0.603*	*1.2E-03*	*2.8E-04*	*6.4E-05*	*3.2E-05*
All Carp Samples in 1990s	1.010	2.0E-03	4.7E-04	1.1E-04	5.4E-05
All Perch Samples in 1990s	0.528	1.1E-03	2.4E-04	5.6E-05	2.8E-05
All Walleye Samples in 1990s	0.541	1.1E-03	2.5E-04	5.8E-05	2.9E-05
All White Bass Samples in 1990s	0.852	1.7E-03	3.9E-04	9.1E-05	4.5E-05
De Pere to Green Bay					
All Fish Samples in 1990s	*1.344*	*2.7E-03*	*6.2E-04*	*1.4E-04*	*7.2E-05*
All Carp Samples in 1990s	3.023	6.0E-03	1.4E-03	3.2E-04	1.6E-04
All Perch Samples in 1990s	1.052	2.1E-03	4.9E-04	1.1E-04	5.6E-05
All Walleye Samples in 1990s	1.347	2.7E-03	6.2E-04	1.4E-04	7.2E-05
All White Bass Samples in 1990s	2.295	4.6E-03	1.1E-03	2.4E-04	1.2E-04
Lake Winnebago					
All Fish Samples in the 1990s	0.063	1.3E-04	2.9E-05	6.7E-06	3.4E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-92 Cancer Risks by Green Bay Zone Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A					
All Fish Samples in 1990s	*1.357*	*2.7E-03*	*6.3E-04*	*1.4E-04*	*7.2E-05*
All Carp Samples in 1990s	0.126	2.5E-04	5.8E-05	1.3E-05	6.7E-06
All Perch Samples in 1990s	1.955	3.9E-03	9.0E-04	2.1E-04	1.0E-04
All Walleye Samples from 1989 on	1.134	2.3E-03	5.2E-04	1.2E-04	6.0E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 3B					
All Fish Samples in 1990s	*1.039*	*2.1E-03*	*4.8E-04*	*1.1E-04*	*5.5E-05*
All Carp Samples in 1990s	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	2.0E-03	4.6E-04	1.1E-04	5.3E-05
All Walleye Samples from 1989 on	1.088	2.2E-03	5.0E-04	1.2E-04	5.8E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 4					
All Fish Samples in 1990s	*0.951*	*1.9E-03*	*4.4E-04*	*1.0E-04*	*5.1E-05*
All Carp Samples in 1990s	2.840	5.7E-03	1.3E-03	3.0E-04	1.5E-04
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	1.4E-03	3.1E-04	7.2E-05	3.6E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Lake Winnebago					
All Fish Samples in the 1990s	0.063	1.3E-04	2.9E-05	6.7E-06	3.4E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-93 Hazard Indices by Lower Fox River Reach Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts					
All Fish Samples in 1990s	*0.960*	*48.0*	*11.1*	*2.6*	*1.3*
All Carp Samples in 1990s	3.173	158.6	36.7	8.5	4.2
All Perch Samples in 1990s	0.152	7.6	1.8	0.4	0.2
All Walleye Samples in 1990s	0.272	13.6	3.1	0.7	0.4
All White Bass Samples in 1990s	0.206	10.3	2.4	0.5	0.3
Appleton to Little Rapids					
All Fish Samples in 1990s	*0.910*	*45.5*	*10.5*	*2.4*	*1.2*
All Carp Samples in 1990s	1.368	68.4	15.8	3.6	1.8
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	15.0	3.5	0.8	0.4
All White Bass Samples in 1990s	0.983	49.1	11.4	2.6	1.3
Little Rapids to De Pere					
All Fish Samples in 1990s	*0.603*	*30.1*	*7.0*	*1.6*	*0.8*
All Carp Samples in 1990s	1.010	50.5	11.7	2.7	1.3
All Perch Samples in 1990s	0.528	26.4	6.1	1.4	0.7
All Walleye Samples in 1990s	0.541	27.0	6.2	1.4	0.7
All White Bass Samples in 1990s	0.852	42.6	9.8	2.3	1.1
De Pere to Green Bay					
All Fish Samples in 1990s	*1.344*	*67.2*	*15.5*	*3.6*	*1.8*
All Carp Samples in 1990s	3.023	151.1	34.9	8.1	4.0
All Perch Samples in 1990s	1.052	52.6	12.2	2.8	1.4
All Walleye Samples in 1990s	1.347	67.3	15.6	3.6	1.8
All White Bass Samples in 1990s	2.295	114.7	26.5	6.1	3.1
Lake Winnebago					
All Fish Samples in the 1990s	0.063	3.1	0.7	0.2	0.1

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-94 Hazard Indices by Green Bay Zone Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A					
All Fish Samples in 1990s	*1.357*	*67.8*	*15.7*	*3.6*	*1.8*
All Carp Samples in 1990s	0.126	6.3	1.5	0.3	0.2
All Perch Samples in 1990s	1.955	97.7	22.6	5.2	2.6
All Walleye Samples from 1989 on	1.134	56.7	13.1	3.0	1.5
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 3B					
All Fish Samples in 1990s	*1.039*	*51.9*	*12.0*	*2.8*	*1.4*
All Carp Samples in 1990s	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	50.0	11.5	2.7	1.3
All Walleye Samples from 1989 on	1.088	54.4	12.6	2.9	1.4
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 4					
All Fish Samples in 1990s	*0.951*	*47.5*	*11.0*	*2.5*	*1.3*
All Carp Samples in 1990s	2.840	141.9	32.8	7.6	3.8
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	33.9	7.8	1.8	0.9
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Lake Winnebago					
All Fish Samples in the 1990s	0.063	3.1	0.7	0.2	0.1

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-95 Results of Probabilistic Analysis for Recreational Anglers Using Little Lake Butte des Morts Fish Concentrations

	Recreational Angler							
	(West *et al.*, 1989)		(West *et al.*, 1993)		(Fiore *et al.*, 1989)		(Exponent, 2000)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles								
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.6E-09	3.9E-03
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-07	9.5E-02
10.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.3E-08	2.7E-02	5.6E-07	1.5E-01
15.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-06	2.0E-01	9.0E-07	2.2E-01
20.0%	8.5E-07	1.9E-01	0.0E+00	0.0E+00	2.4E-06	3.8E-01	1.3E-06	2.9E-01
25.0%	2.8E-06	4.7E-01	0.0E+00	0.0E+00	4.2E-06	5.6E-01	1.7E-06	3.5E-01
30.0%	5.6E-06	8.3E-01	0.0E+00	0.0E+00	6.5E-06	7.6E-01	2.1E-06	4.3E-01
35.0%	9.4E-06	1.2E+00	0.0E+00	0.0E+00	9.1E-06	1.0E+00	2.7E-06	5.1E-01
40.0%	1.4E-05	1.7E+00	0.0E+00	0.0E+00	1.2E-05	1.3E+00	3.3E-06	6.1E-01
45.0%	2.0E-05	2.2E+00	0.0E+00	0.0E+00	1.6E-05	1.5E+00	4.1E-06	7.1E-01
50.0%	2.7E-05	2.8E+00	0.0E+00	0.0E+00	2.1E-05	1.8E+00	5.0E-06	8.3E-01
55.0%	3.5E-05	3.3E+00	0.0E+00	0.0E+00	2.7E-05	2.2E+00	6.2E-06	9.7E-01
60.0%	4.5E-05	4.0E+00	0.0E+00	0.0E+00	3.4E-05	2.8E+00	7.7E-06	1.1E+00
65.0%	5.8E-05	4.9E+00	0.0E+00	0.0E+00	4.3E-05	3.4E+00	9.4E-06	1.3E+00
70.0%	7.5E-05	5.7E+00	1.6E-05	7.0E+00	5.6E-05	4.2E+00	1.2E-05	1.6E+00
75.0%	9.7E-05	6.7E+00	6.7E-05	8.3E+00	7.2E-05	5.0E+00	1.5E-05	1.9E+00
80.0%	1.2E-04	7.8E+00	1.3E-04	1.0E+01	9.4E-05	6.3E+00	1.8E-05	2.3E+00
85.0%	1.6E-04	9.2E+00	2.2E-04	1.7E+01	1.3E-04	8.1E+00	2.5E-05	2.9E+00
90.0%	2.2E-04	1.1E+01	3.4E-04	2.0E+01	1.8E-04	1.0E+01	3.5E-05	3.9E+00
95.0%	**3.1E-04**	**1.3E+01**	**6.1E-04**	**2.7E+01**	**3.0E-04**	**1.3E+01**	**6.0E-05**	**5.8E+00**
98.0%	4.3E-04	1.6E+01	9.3E-04	4.1E+01	4.4E-04	2.1E+01	1.1E-04	9.2E+00
99.0%	5.1E-04	1.7E+01	1.2E-03	5.3E+01	5.8E-04	2.5E+01	1.4E-04	1.2E+01
99.9%	6.8E-04	2.1E+01	2.7E-03	1.4E+02	1.1E-03	3.4E+01	3.5E-04	2.7E+01
100.0%	8.2E-04	2.8E+01	5.5E-03	1.8E+02	1.3E-03	4.6E+01	1.5E-03	4.8E+01
Statistics								
Mean	7.3E-05	4.2E+00	1.0E-04	5.9E+00	6.6E-05	3.8E+00	1.5E-05	1.6E+00
Standard Deviation	1.1E-04	4.4E+00	2.7E-04	1.2E+01	1.2E-04	5.1E+00	3.6E-05	2.6E+00
Point Estimates								
CTE	6.4E-05	4.0E+00	9.1E-05	5.7E+00	5.9E-05	3.7E+00	1.4E-05	1.6E+00
RME	3.5E-04	1.3E+01	7.0E-04	2.6E+01	3.3E-04	1.2E+01	1.5E-04	5.7E+00
Variance	1.2E-08	1.9E+01	7.4E-08	1.5E+02	1.4E-08	2.6E+01	1.3E-09	6.7E+00
Kurtosis	2.4E+00	1.2E+00	5.6E+00	4.4E+00	3.8E+00	2.5E+00	1.4E+01	5.7E+00
Skewness	9.6E+00	3.8E+00	5.8E+01	3.8E+01	2.3E+01	1.1E+01	4.4E+02	6.2E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-96 Results of Probabilistic Analysis for High-intake Fish Consumers Using Little Lake Butte des Morts Fish Concentrations

	High-intake Fish Consumers					
	Low-income Minority (West *et al.*, 1993)		Hmong (Hutchison & Kraft, 1994)		Hmong/Laotian (Hutchison, 1999)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles						
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10.0%	0.0E+00	0.0E+00	1.2E-06	1.3E+00	0.0E+00	0.0E+00
15.0%	0.0E+00	0.0E+00	5.7E-06	1.5E+00	0.0E+00	0.0E+00
20.0%	0.0E+00	0.0E+00	9.5E-06	1.7E+00	0.0E+00	0.0E+00
25.0%	0.0E+00	0.0E+00	1.4E-05	1.9E+00	0.0E+00	0.0E+00
30.0%	0.0E+00	0.0E+00	1.9E-05	2.1E+00	0.0E+00	0.0E+00
35.0%	0.0E+00	0.0E+00	2.5E-05	2.3E+00	0.0E+00	0.0E+00
40.0%	0.0E+00	0.0E+00	3.2E-05	2.5E+00	5.1E-07	1.3E+00
45.0%	0.0E+00	0.0E+00	3.9E-05	2.7E+00	6.1E-06	2.0E+00
50.0%	0.0E+00	0.0E+00	4.8E-05	3.1E+00	1.1E-05	2.1E+00
55.0%	2.8E-05	6.1E+00	5.7E-05	3.9E+00	1.6E-05	2.3E+00
60.0%	6.6E-05	7.1E+00	6.8E-05	4.6E+00	2.4E-05	2.4E+00
65.0%	1.0E-04	9.5E+00	8.1E-05	5.3E+00	3.3E-05	2.5E+00
70.0%	1.6E-04	1.6E+01	9.8E-05	6.2E+00	4.2E-05	2.6E+00
75.0%	2.3E-04	1.9E+01	1.2E-04	7.4E+00	5.4E-05	2.7E+00
80.0%	3.1E-04	2.2E+01	1.6E-04	1.0E+01	6.9E-05	2.9E+00
85.0%	4.6E-04	2.5E+01	2.2E-04	1.6E+01	8.5E-05	3.1E+00
90.0%	6.7E-04	2.8E+01	3.2E-04	2.1E+01	1.0E-04	4.0E+00
95.0%	**1.0E-03**	**3.9E+01**	**6.0E-04**	**2.8E+01**	**1.5E-04**	**1.1E+01**
98.0%	2.3E-03	1.6E+02	1.0E-03	4.9E+01	3.7E-04	1.4E+01
99.0%	4.1E-03	1.8E+02	1.3E-03	5.6E+01	4.6E-04	2.6E+01
99.9%	7.2E-03	2.2E+02	2.5E-03	7.4E+01	1.2E-03	3.5E+01
100.0%	8.4E-03	2.6E+02	3.0E-03	8.7E+01	1.4E-03	4.1E+01
Statistics						
Mean	2.5E-04	1.5E+01	1.3E-04	7.5E+00	4.4E-05	2.6E+00
Standard Deviation	7.0E-04	3.2E+01	2.7E-04	1.1E+01	9.8E-05	4.3E+00
Point Estimates						
CTE	2.3E-04	1.4E+01	1.1E-04	7.1E+00	4.0E-05	2.5E+00
RME	9.8E-04	3.7E+01	7.2E-04	2.7E+01	2.9E-04	1.1E+01
Variance	4.9E-07	1.0E+03	7.1E-08	1.2E+02	9.6E-09	1.8E+01
Kurtosis	6.0E+00	4.0E+00	4.6E+00	2.9E+00	6.0E+00	4.0E+00
Skewness	4.8E+01	2.0E+01	3.1E+01	1.3E+01	5.4E+01	2.3E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-97 Results of Probabilistic Analysis for Recreational Anglers Using De Pere to Green Bay Fish Concentrations

	Recreational Angler							
	(West *et al.*, 1989)		(West *et al.*, 1993)		(Fiore *et al.*, 1989)		(Exponent, 2000)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles								
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.4E-09	6.4E-03
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E-07	1.6E-01
10.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-07	3.8E-02	9.3E-07	2.4E-01
15.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E-06	2.9E-01	1.4E-06	3.3E-01
20.0%	1.3E-06	2.8E-01	0.0E+00	0.0E+00	3.5E-06	5.4E-01	1.9E-06	4.2E-01
25.0%	3.8E-06	6.4E-01	0.0E+00	0.0E+00	5.9E-06	8.1E-01	2.4E-06	5.1E-01
30.0%	7.9E-06	1.1E+00	0.0E+00	0.0E+00	9.1E-06	1.1E+00	3.0E-06	6.2E-01
35.0%	1.3E-05	1.6E+00	0.0E+00	0.0E+00	1.3E-05	1.4E+00	3.8E-06	7.3E-01
40.0%	1.9E-05	2.2E+00	0.0E+00	0.0E+00	1.7E-05	1.8E+00	4.8E-06	8.7E-01
45.0%	2.7E-05	3.0E+00	0.0E+00	0.0E+00	2.3E-05	2.2E+00	5.9E-06	1.0E+00
50.0%	3.6E-05	3.8E+00	0.0E+00	0.0E+00	3.0E-05	2.5E+00	7.2E-06	1.2E+00
55.0%	4.9E-05	4.6E+00	0.0E+00	0.0E+00	3.8E-05	3.1E+00	8.8E-06	1.4E+00
60.0%	6.3E-05	5.6E+00	0.0E+00	0.0E+00	4.9E-05	3.9E+00	1.1E-05	1.6E+00
65.0%	8.1E-05	6.6E+00	0.0E+00	0.0E+00	6.2E-05	4.9E+00	1.3E-05	1.9E+00
70.0%	1.1E-04	7.8E+00	2.0E-05	1.0E+01	7.9E-05	5.9E+00	1.6E-05	2.2E+00
75.0%	1.3E-04	9.2E+00	8.9E-05	1.2E+01	9.9E-05	7.0E+00	2.0E-05	2.6E+00
80.0%	1.7E-04	1.1E+01	1.9E-04	1.4E+01	1.3E-04	8.7E+00	2.6E-05	3.2E+00
85.0%	2.2E-04	1.3E+01	3.1E-04	2.3E+01	1.8E-04	1.1E+01	3.3E-05	4.0E+00
90.0%	3.0E-04	1.5E+01	4.7E-04	2.8E+01	2.6E-04	1.4E+01	4.8E-05	5.2E+00
95.0%	**4.4E-04**	**1.8E+01**	**8.5E-04**	**3.8E+01**	**4.2E-04**	**1.8E+01**	**7.9E-05**	**7.7E+00**
98.0%	6.1E-04	2.1E+01	1.3E-03	5.7E+01	6.4E-04	2.9E+01	1.4E-04	1.2E+01
99.0%	7.2E-04	2.3E+01	1.7E-03	7.4E+01	8.3E-04	3.4E+01	1.9E-04	1.7E+01
99.9%	9.2E-04	2.8E+01	3.9E-03	1.8E+02	1.4E-03	4.5E+01	5.3E-04	3.3E+01
100.0%	1.2E-03	3.1E+01	1.0E-02	2.6E+02	1.7E-03	7.1E+01	1.3E-03	5.6E+01
Statistics								
Mean	1.0E-04	5.8E+00	1.5E-04	8.3E+00	9.3E-05	5.3E+00	2.0E-05	2.3E+00
Standard Deviation	1.5E-04	6.0E+00	4.0E-04	1.7E+01	1.7E-04	7.0E+00	4.2E-05	3.4E+00
Point Estimates								
CTE	9.0E-05	5.6E+00	1.3E-04	8.0E+00	8.3E-05	5.2E+00	2.0E-05	2.3E+00
RME	4.9E-04	1.8E+01	9.7E-04	3.7E+01	4.6E-04	1.7E+01	2.1E-04	8.0E+00
Variance	2.4E-08	3.6E+01	1.6E-07	2.9E+02	2.8E-08	4.9E+01	1.8E-09	1.1E+01
Kurtosis	2.4E+00	1.1E+00	7.1E+00	4.2E+00	3.7E+00	2.4E+00	8.7E+00	4.9E+00
Skewness	9.4E+00	3.5E+00	9.9E+01	3.6E+01	2.2E+01	1.1E+01	1.4E+02	4.2E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-98 Results of Probabilistic Analysis for High-intake Fish Consumers Using De Pere to Green Bay Fish Concentrations

	High-intake Fish Consumers					
	Low-income Minority (West *et al.*, 1993)		Hmong (Hutchison & Kraft, 1994)		Hmong/Laotian (Hutchison & Kraft, 1994)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles						
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10.0%	0.0E+00	0.0E+00	2.1E-06	1.9E+00	0.0E+00	0.0E+00
15.0%	0.0E+00	0.0E+00	8.0E-06	2.2E+00	0.0E+00	0.0E+00
20.0%	0.0E+00	0.0E+00	1.3E-05	2.4E+00	0.0E+00	0.0E+00
25.0%	0.0E+00	0.0E+00	2.0E-05	2.6E+00	0.0E+00	0.0E+00
30.0%	0.0E+00	0.0E+00	2.7E-05	2.9E+00	0.0E+00	0.0E+00
35.0%	0.0E+00	0.0E+00	3.5E-05	3.2E+00	0.0E+00	0.0E+00
40.0%	0.0E+00	0.0E+00	4.5E-05	3.5E+00	7.3E-07	2.4E+00
45.0%	0.0E+00	0.0E+00	5.5E-05	3.8E+00	9.2E-06	2.9E+00
50.0%	0.0E+00	0.0E+00	6.7E-05	4.2E+00	1.5E-05	3.1E+00
55.0%	3.6E-05	8.8E+00	8.1E-05	5.5E+00	2.4E-05	3.2E+00
60.0%	8.8E-05	9.9E+00	9.4E-05	6.4E+00	3.4E-05	3.3E+00
65.0%	1.5E-04	1.3E+01	1.1E-04	7.4E+00	4.7E-05	3.5E+00
70.0%	2.1E-04	2.2E+01	1.3E-04	8.5E+00	6.1E-05	3.6E+00
75.0%	3.1E-04	2.6E+01	1.7E-04	1.0E+01	7.7E-05	3.8E+00
80.0%	4.1E-04	3.1E+01	2.3E-04	1.5E+01	9.8E-05	4.0E+00
85.0%	6.2E-04	3.5E+01	3.1E-04	2.2E+01	1.2E-04	4.2E+00
90.0%	9.3E-04	3.9E+01	4.8E-04	3.0E+01	1.4E-04	5.0E+00
95.0%	**1.4E-03**	**5.5E+01**	**8.6E-04**	**4.0E+01**	**2.0E-04**	**1.5E+01**
98.0%	3.5E-03	2.2E+02	1.4E-03	6.7E+01	5.2E-04	1.9E+01
99.0%	6.1E-03	2.4E+02	1.7E-03	7.9E+01	6.8E-04	3.6E+01
99.9%	9.8E-03	2.9E+02	3.2E-03	1.0E+02	1.6E-03	4.6E+01
100.0%	1.1E-02	3.4E+02	4.1E-03	1.2E+02	2.0E-03	5.1E+01
Statistics						
Mean	3.6E-04	2.0E+01	1.9E-04	1.1E+01	6.3E-05	3.6E+00
Standard Deviation	1.0E-03	4.4E+01	3.6E-04	1.5E+01	1.4E-04	5.9E+00
Point Estimates						
CTE	3.2E-04	2.0E+01	1.6E-04	9.9E+00	5.6E-05	3.5E+00
RME	1.4E-03	5.1E+01	1.0E-03	3.8E+01	4.0E-04	1.5E+01
Variance	1.0E-06	2.0E+03	1.3E-07	2.2E+02	1.9E-08	3.4E+01
Kurtosis	5.9E+00	3.9E+00	4.3E+00	2.9E+00	5.9E+00	3.9E+00
Skewness	4.4E+01	1.9E+01	2.7E+01	1.3E+01	5.2E+01	2.2E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-99 Summary of Uncertainty Evaluation—Little Lake Butte des Morts Reach

		Recreational Angler				High-intake Fish Consumer			
		Mean	Range Minimum		Range Maximum	Mean	Range Minimum		Range Maximum
Risk	**Mean**	**6.5E-05**	**1.5E-05**	**to**	**1.0E-04**	**1.4E-04**	**4.4E-05**	**to**	**2.5E-04**
	5th percentile	7.5E-08	1.0E-08	to	3.0E-07	0.0E+00	1.0E-08	to	1.0E-08
	25th percentile	2.2E-06	1.0E-08	to	4.2E-06	4.8E-06	1.0E-08	to	1.4E-05
	50th percentile	1.3E-05	1.0E-08	to	2.7E-05	2.0E-05	1.0E-08	to	4.8E-05
	75th percentile	6.3E-05	1.5E-05	to	9.7E-05	1.4E-04	5.4E-05	to	2.3E-04
	90th percentile	1.9E-04	3.5E-05	to	3.4E-04	3.6E-04	1.0E-04	to	6.7E-04
	95th percentile	**3.2E-04**	**6.0E-05**	**to**	**6.1E-04**	**5.9E-04**	**1.5E-04**	**to**	**1.0E-03**
Hazard Index	**Mean**	**3.9E+00**	**1.6E+00**	**to**	**5.9E+00**	**8.2E+00**	**2.6E+00**	**to**	**1.5E+01**
	5th percentile	2.4E-02	0.0E+00	to	9.5E-02	0.0E+00	0.0E+00	to	0.0E+00
	25th percentile	3.5E-01	0.0E+00	to	5.6E-01	6.2E-01	0.0E+00	to	1.9E+00
	50th percentile	1.4E+00	0.0E+00	to	2.8E+00	1.7E+00	0.0E+00	to	3.1E+00
	75th percentile	5.5E+00	1.9E+00	to	8.3E+00	9.6E+00	2.7E+00	to	1.9E+01
	90th percentile	1.1E+01	3.9E+00	to	2.0E+01	1.8E+01	4.0E+00	to	2.8E+01
	95th percentile	**1.5E+01**	**5.8E+00**	**to**	**2.7E+01**	**2.6E+01**	**1.1E+01**	**to**	**3.9E+01**

Table 5-100 Summary of Uncertainty Evaluation—De Pere to Green Bay Reach

		Recreational Angler				High-intake Fish Consumer			
		Mean	Range			Mean	Range		
			Minimum		Maximum		Minimum		Maximum
Risk	**Mean**	**9.0E-05**	**2.0E-05**	**to**	**1.5E-04**	**2.0E-04**	**6.3E-05**	**to**	**3.6E-04**
	5th percentile	1.2E-07	1.0E-08	to	4.8E-07	0.0E+00	1.0E-08	to	1.0E-08
	25th percentile	3.0E-06	1.0E-08	to	5.9E-06	6.7E-06	1.0E-08	to	2.0E-05
	50th percentile	1.8E-05	1.0E-08	to	3.6E-05	2.8E-05	1.0E-08	to	6.7E-05
	75th percentile	8.5E-05	2.0E-05	to	1.3E-04	1.9E-04	7.7E-05	to	3.1E-04
	90th percentile	2.7E-04	4.8E-05	to	4.7E-04	5.1E-04	1.4E-04	to	9.3E-04
	95th percentile	**4.5E-04**	**7.9E-05**	**to**	**8.5E-04**	**8.3E-04**	**2.0E-04**	**to**	**1.4E-03**
Hazard Index	**Mean**	**5.4E+00**	**2.3E+00**	**to**	**8.3E+00**	**1.1E+01**	**3.6E+00**	**to**	**2.0E+01**
	5th percentile	3.9E-02	0.0E+00	to	1.6E-01	0.0E+00	0.0E+00	to	0.0E+00
	25th percentile	4.9E-01	0.0E+00	to	8.1E-01	8.7E-01	0.0E+00	to	2.6E+00
	50th percentile	1.9E+00	0.0E+00	to	3.8E+00	2.4E+00	0.0E+00	to	4.2E+00
	75th percentile	7.6E+00	2.6E+00	to	1.2E+01	1.3E+01	3.8E+00	to	2.6E+01
	90th percentile	1.6E+01	5.2E+00	to	2.8E+01	2.5E+01	5.0E+00	to	3.9E+01
	95th percentile	**2.0E+01**	**7.7E+00**	**to**	**3.8E+01**	**3.7E+01**	**1.5E+01**	**to**	**5.5E+01**

Table 5-101 Child-to-Adult Fish Ingestion Rate Ratios

Study	Fish Type	Age Group	Mean Ingestion Rate (g/day)	Child-to-Adult Ratio
EPA, 1996f [1]	Freshwater/Estuarine	14 & under 15–44	2.35 6.64	0.35
	Marine	14 & under 15–44	9.02 14.88	0.61
	All Fish	14 & under 15–44	11.36 21.51	0.53
EPA, 1996f [1]	Freshwater/Estuarine	14 & under 15–44	56.95 91.66	0.62
	Marine	14 & under 15–44	95.56 115.41	0.83
	All Fish	14 & under 15–44	96.07 136.12	0.71
West *et al.* , 1989 [3]	Recreational Fish	1–5 6–10 Adult	5.63 7.94 12	0.47 0.66
Average for All Ratios				0.60

Notes:

[1] Per capita distribution of fish intake, uncooked fish weight.

[2] Consumers only distribution of fish intake, uncooked fish weight.

[3] Households that participate in recreational fishing; uncooked fish weight.

Table 5-102 Intake Assumptions and Toxicological Parameters for the Recreational Angler Child

Parameter	1989 Michigan Study RME (West *et al.*, 1989)	1989 Michigan Study CTE (West *et al.*, 1989)	1993 Michigan Study RME (West *et al.*, 1993)	1993 Michigan Study CTE (West *et al.*, 1993)	Average of Michigan Studies RME (West *et al.*, 1989, 1993)	Average of Michigan Studies CTE (West *et al.*, 1989, 1993)	1989 Wisconsin Study RME (Fiore *et al.*, 1989)	1989 Wisconsin Study CTE (Fiore *et al.*, 1989)
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	39	12	78	17	59	15	227	227
EF (days/year or meals/year)	365	365	365	365	365	365	59	18
Basis: Annualized IR								
IR (g/day)	39	12	78	17	59	15	37	11
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	63	19	125	27	94	23	59	18
Other Intake Parameters								
Child to Adult Fish Ingestion Ratio	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	7	7	7	7	7	7	7	7
BW (kg)	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
ATnc (days)	2,555	2,555	2,555	2,555	2,555	2,555	2,555	2,555
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	6.6E-04	2.0E-04	1.3E-03	2.9E-04	9.9E-04	2.4E-04	6.2E-04	1.9E-04

Table 5-103 Intake Assumptions and Toxicological Parameters for the High-intake Fish Consumer Child

Parameter	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	110	43	227	227	227	227	227	227
EF (days/year or meals/year)	365	365	89	27	130	34	52	12
Basis: Annualized IR								
IR (g/day)	110	43	55	17	81	21	32	7
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	177	69	89	27	130	34	52	12
Other Intake Parameters								
Child to Adult Fish Ingestion Ratio	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	7	7	7	7	7	7	7	7
BW (kg)	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
ATnc (days)	2,555	2,555	2,555	2,555	2,555	2,555	2,555	2,555
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	1.9E-03	7.2E-04	9.3E-04	2.8E-04	1.4E-03	3.6E-04	5.5E-04	1.3E-04

Table 5-104 Hazard Indices by Lower Fox River Reach for the Recreational Angler Child

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989)		1993 Michigan Study (West *et al.*, 1993)		Average of Michigan Studies (West *et al.*, 1989, 1993)		1989 Wisconsin Study (Fiore *et al.*, 1989)	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*31.6*	*9.7*	*63.1*	*13.8*	*47.3*	*11.7*	*29.7*	*9.1*
All Carp Samples in 1990s	3.173	104.3	32.1	208.6	45.5	156.4	38.8	98.1	29.9
All Perch Samples in 1990s	0.152	5.0	1.5	10.0	2.2	7.5	1.9	4.7	1.4
All Walleye Samples in 1990s	0.272	8.9	2.8	17.9	3.9	13.4	3.3	8.4	2.6
All White Bass Samples in 1990s	0.206	6.8	2.1	13.5	2.9	10.1	2.5	6.4	1.9
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*44.2*	*13.6*	*88.4*	*19.3*	*66.3*	*16.4*	*41.6*	*12.7*
All Carp Samples in 1990s	3.023	99.3	30.6	198.7	43.3	149.0	36.9	93.5	28.5
All Perch Samples in 1990s	1.052	34.6	10.6	69.2	15.1	51.9	12.9	32.5	9.9
All Walleye Samples in 1990s	1.347	44.3	13.6	88.5	19.3	66.4	16.5	41.7	12.7
All White Bass Samples in 1990s	2.295	75.4	23.2	150.8	32.9	113.1	28.0	71.0	21.6
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.1	0.6	4.1	0.9	3.1	0.8	1.9	0.6

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-105 Hazard Indices by Lower Fox River Reach for the High-intake Fish Consumer Child

Location	Average Fish Concentration (mg/kg)	Low-income Minority (West *et al.*, 1993) RME	Low-income Minority (West *et al.*, 1993) CTE	Native American (Peterson *et al.*, 1994 and Fiore *et al.*, 1989) RME	Native American (Peterson *et al.*, 1994 and Fiore *et al.*, 1989) CTE	Hmong (Hutchison and Kraft, 1994) RME	Hmong (Hutchison and Kraft, 1994) CTE	Hmong/Laotian (Hutchison, 1999) RME	Hmong/Laotian (Hutchison, 1999) CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*89.0*	*34.8*	*44.8*	*13.6*	*65.4*	*17.1*	*26.2*	*6.0*
All Carp Samples in 1990s	3.173	294.2	115.0	148.0	44.9	216.2	56.5	86.5	20.0
All Perch Samples in 1990s	0.152	14.1	5.5	7.1	2.1	10.3	2.7	4.1	1.0
All Walleye Samples in 1990s	0.272	25.2	9.9	12.7	3.9	18.5	4.9	7.4	1.7
All White Bass Samples in 1990s	0.206	19.1	7.5	9.6	2.9	14.0	3.7	5.6	1.3
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*124.6*	*48.7*	*62.7*	*19.0*	*91.6*	*24.0*	*36.6*	*8.5*
All Carp Samples in 1990s	3.023	280.2	109.5	141.0	42.8	205.9	53.9	82.4	19.0
All Perch Samples in 1990s	1.052	97.5	38.1	49.1	14.9	71.7	18.8	28.7	6.6
All Walleye Samples in 1990s	1.347	124.9	48.8	62.8	19.1	91.8	24.0	36.7	8.5
All White Bass Samples in 1990s	2.295	212.7	83.2	107.0	32.5	156.3	40.9	62.5	14.4
Lake Winnebago									
All Fish Samples in the 1990s	0.063	5.8	2.3	2.9	0.9	4.3	1.1	1.7	0.4

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-106 Risk-based Fish Concentrations for the Recreational Angler

Risk or Hazard Index Level	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Risk:								
1E-06	2.8E-03	1.5E-02	1.4E-03	1.1E-02	1.8E-03	1.2E-02	2.9E-03	1.6E-02
1E-05	2.8E-02	1.5E-01	1.4E-02	1.1E-01	1.8E-02	1.2E-01	2.9E-02	1.6E-01
1E-04	2.8E-01	1.5E+00	1.4E-01	1.1E+00	1.8E-01	1.2E+00	2.9E-01	1.6E+00
Hazard Index:								
1	7.4E-02	2.4E-01	3.7E-02	1.7E-01	4.9E-02	2.0E-01	7.8E-02	2.6E-01

Note:

Fish concentrations are in mg PCB/kg fish.

Table 5-107 Risk-based Fish Concentrations for the High-intake Fish Consumer

Risk or Hazard Index Level	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Risk:								
1E-06	9.8E-04	4.2E-03	1.9E-03	1.1E-02	1.3E-03	8.5E-03	3.3E-03	2.4E-02
1E-05	9.8E-03	4.2E-02	1.9E-02	1.1E-01	1.3E-02	8.5E-02	3.3E-02	2.4E-01
1E-04	9.8E-02	4.2E-01	1.9E-01	1.1E+00	1.3E-01	8.5E-01	3.3E-01	2.4E+00
Hazard Index:								
1	2.6E-02	6.7E-02	5.2E-02	1.7E-01	3.6E-02	1.4E-01	8.9E-02	3.8E-01

Note:
Fish concentrations are in mg PCB/kg fish.

Table 5-108 Risk-based Fish Concentrations Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Risk or Hazard Index Level	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Risk:				
1E-06	5.0E-04	2.2E-03	9.4E-03	1.9E-02
1E-05	5.0E-03	2.2E-02	9.4E-02	1.9E-01
1E-04	5.0E-02	2.2E-01	9.4E-01	1.9E+00
Hazard Index:				
1	2.0E-02	8.7E-02	3.8E-01	7.5E-01

Note:

Fish concentrations are in mg PCB/kg fish.

Table 5-109 Cancer Risks for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to De Pere Reach	De Pere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
RME with Average Concentrations	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
CTE with Average Concentrations	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
Subsistence Angler					
RME with Upper-bound Concentrations	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
RME with Average Concentrations	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
CTE with Average Concentrations	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Hunter					
RME with Upper-bound Concentrations	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
RME with Average Concentrations	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
CTE with Average Concentrations	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Drinking Water User					
RME with Upper-bound Concentrations	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.2E-08
Local Resident					
RME with Upper-bound Concentrations	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	2.2E-07	7.3E-08	8.1E-08	2.0E-07	5.2E-08
Recreational Water User—Wader					
RME with Upper-bound Concentrations	5.0E-07	9.9E-08	1.1E-07	2.5E-07	7.4E-08
Marine Construction Worker					
RME with Upper-bound Concentrations	1.5E-06	2.2E-07	2.8E-07	5.5E-07	1.5E-07

Notes:

Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.

EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.

Table 5-110 Noncancer Hazard Indices for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to De Pere Reach	De Pere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	76.2	107.1	17.9	59.8	55.9
RME with Average Concentrations	59.1	83.9	14.6	52.8	53.2
CTE with Average Concentrations	15.0	21.3	3.7	13.4	13.5
Subsistence Angler					
RME with Upper-bound Concentrations	104.3	146.8	24.5	82.0	86.6
RME with Average Concentrations	80.9	114.9	20.0	72.4	72.8
CTE with Average Concentrations	21.2	30.1	5.2	18.9	19.0
Hunter					
RME with Upper-bound Concentrations	1.7	2.0	3.1	2.0	2.1
RME with Average Concentrations	0.9	1.3	1.1	0.6	0.8
CTE with Average Concentrations	0.5	0.7	0.6	0.3	0.4
Drinking Water User					
RME with Upper-bound Concentrations	3.56	0.10	3.22	0.33	0.19
RME with Upper-bound Concentrations and Recent Mercury Data	0.17	0.10	0.16	0.33	0.19
Local Resident					
RME with Upper-bound Concentrations	3.823	0.043	1.194	0.004	0.237
RME with Upper-bound Concentrations and Recent Mercury Data	0.097	0.043	0.086	0.004	0.237
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	0.059	0.008	0.022	0.015	0.004
Recreational Water User—Wader					
RME with Upper-bound Concentrations	0.111	0.010	0.019	0.022	0.003
Marine Construction Worker					
RME with Upper-bound Concentrations	0.272	0.011	0.065	0.018	0.012

Note:

Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

Table 5-111 Summary of Cancer Risks and Noncancer Hazard Indices for Anglers Exposed to PCBs from Ingestion of Fish

Location	Recreational Anglers			High-intake Fish Consumer		
	Lowest	Median	Highest	Lowest	Median	Highest
Cancer Risks						
Lower Fox River						
All Fish Samples						
RME Scenario	*2.1E-04*	*4.5E-04*	*9.7E-04*	*1.8E-04*	*5.5E-04*	*1.4E-03*
CTE Scenario	*3.8E-05*	*6.9E-05*	*1.3E-04*	*2.5E-05*	*9.9E-05*	*3.2E-04*
All Carp Samples						
RME Scenario	1.1E-03	1.4E-03	2.3E-03	3.0E-04	1.0E-03	3.2E-03
CTE Scenario	2.0E-04	2.3E-04	3.0E-04	4.2E-05	2.0E-04	7.6E-04
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	7.0E-05	3.2E-04	1.7E-03	4.6E-05	3.1E-04	2.3E-03
CTE Scenario	1.3E-05	5.2E-05	2.2E-04	6.3E-06	5.9E-05	5.5E-04
Green Bay						
All Fish Samples						
RME Scenario	*3.2E-04*	*5.0E-04*	*9.8E-04*	*2.9E-04*	*7.1E-04*	*1.4E-03*
CTE Scenario	*5.9E-05*	*8.4E-05*	*1.3E-04*	*4.0E-05*	*1.2E-04*	*3.3E-04*
All Carp Samples						
RME Scenario	NA	NA	NA	NA	NA	NA
CTE Scenario	NA	NA	NA	NA	NA	NA
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	2.3E-04	5.2E-04	1.4E-03	2.0E-04	6.4E-04	2.0E-03
CTE Scenario	4.2E-05	7.8E-05	1.9E-04	2.8E-05	1.1E-04	4.7E-04
Lake Winnebago						
RME Scenario	2.1E-05	2.9E-05	4.6E-05	1.9E-05	4.0E-05	6.4E-05
CTE Scenario	3.9E-06	4.7E-06	6.0E-06	2.6E-06	6.7E-06	1.5E-05
Hazard Indices						
Lower Fox River						
All Fish Samples						
RME Scenario	*7.7*	*16.8*	*36.5*	*6.8*	*20.8*	*51.5*
CTE Scenario	*2.4*	*4.3*	*8.0*	*1.6*	*6.2*	*20.1*
All Carp Samples						
RME Scenario	40.5	53.9	86.2	11.4	38.6	121.5
CTE Scenario	12.4	14.6	18.8	2.6	12.6	47.5
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	2.6	12.1	62.3	1.7	11.7	87.9
CTE Scenario	0.8	3.3	13.6	0.4	3.7	34.4
Green Bay						
All Fish Samples						
RME Scenario	*12.1*	*18.9*	*36.9*	*10.7*	*26.5*	*52.0*
CTE Scenario	*3.7*	*5.3*	*8.0*	*2.5*	*7.3*	*20.3*
All Carp Samples						
RME Scenario	NA	NA	NA	NA	NA	NA
CTE Scenario	NA	NA	NA	NA	NA	NA
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	8.7	19.4	53.1	7.6	24.0	74.9
CTE Scenario	2.6	4.9	11.6	1.8	7.0	29.3
Lake Winnebago						
RME Scenario	0.8	1.1	1.7	0.7	1.5	2.4
CTE Scenario	0.2	0.3	0.4	0.2	0.4	0.9

Notes:

All Per., Wal. and Wh. B. Smpl. - All perch, walleye and white bass samples.
Risks and hazard indices were calculated from fish concentrations using samples from the 1990s plus walleye samples in Green Bay from 1989.
The most relevant risk calculations are for the *All Fish Samples* data set, which have been italicized.
Risks and hazard indices calculated for Lake Winnebago fish samples represent background.
Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.
EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.
Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

Table 5-112 Summary of Maximum Cancer Risks and Noncancer Hazard Indices for Anglers Exposed to PCBs from Ingestion of Fish

A. Lower Fox River

Receptor/Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Lake Winnebago
Cancer Risks					
Recreational Angler					
RME Scenario	7.0E-04	6.6E-04	4.4E-04	9.7E-04	4.6E-05
CTE Scenario	9.1E-05	8.6E-05	5.7E-05	1.3E-04	6.0E-06
High-intake Fish Consumer					
RME Scenario	9.8E-04	9.3E-04	6.2E-04	1.4E-03	6.4E-05
CTE Scenario	2.3E-04	2.2E-04	1.4E-04	3.2E-04	1.5E-05
Hazard Indices					
Recreational Angler					
RME Scenario	26.1	24.7	16.4	36.5	1.7
CTE Scenario	5.7	5.4	3.6	8.0	0.4
High-intake Fish Consumer					
RME Scenario	36.8	34.9	23.1	51.5	2.4
CTE Scenario	14.4	13.6	9.0	20.1	0.9

Notes:

Risks and hazard indices were calculated using fish concentrations based on samples from the 1990s.
Risks and hazard indices calculated for Lake Winnebago fish samples represent background.
Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.
EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.
Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

B. Green Bay

Receptor/Scenario	Zone 3A	Zone 3B	Zone 4	Lake Winnebago
Cancer Risks				
Recreational Angler				
RME Scenario	9.8E-04	7.5E-04	6.9E-04	4.6E-05
CTE Scenario	1.3E-04	9.8E-05	9.0E-05	6.0E-06
High-intake Fish Consumer				
RME Scenario	1.4E-03	1.1E-03	9.7E-04	6.4E-05
CTE Scenario	3.3E-04	2.5E-04	2.3E-04	1.5E-05
Hazard Indices				
Recreational Angler				
RME Scenario	36.9	28.2	25.8	1.7
CTE Scenario	8.0	6.2	5.6	0.4
High-intake Fish Consumer				
RME Scenario	52.0	39.8	36.4	2.4
CTE Scenario	20.3	15.6	14.2	0.9

Notes:

Risks and hazard indices were calculated using fish concentrations based on samples from the 1990s plus walleye samples in 1989.
Risks and hazard indices calculated for Lake Winnebago fish samples represent background.
Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.
EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.
Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

Table 5-113 Risk-based Fish Concentrations

A. Recreational Anglers

Risk or Noncancer Hazard Index Level	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Risk Level:								
1E-06	2.8E-03	1.5E-02	1.4E-03	1.1E-02	1.8E-03	1.2E-02	2.9E-03	1.6E-02
1E-05	2.8E-02	1.5E-01	1.4E-02	1.1E-01	1.8E-02	1.2E-01	2.9E-02	1.6E-01
1E-04	2.8E-01	1.5E+00	1.4E-01	1.1E+00	1.8E-01	1.2E+00	2.9E-01	1.6E+00
Hazard Index Level:								
1.0	7.4E-02	2.4E-01	3.7E-02	1.7E-01	4.9E-02	2.0E-01	7.8E-02	2.6E-01

B. High-intake Fish Consumers

Risk or Noncancer Hazard Index Level	Low-income Minority (West *et al.*, 1993) RME	CTE	Native American (Peterson *et al.*, 1994 and Fiore *et al.*, 1989) RME	CTE	Hmong (Hutchison and Kraft, 1994) RME	CTE	Hmong/Laotian (Hutchison, 1999) RME	CTE
Risk Level:								
1E-06	9.8E-04	4.2E-03	1.9E-03	1.1E-02	1.3E-03	8.5E-03	3.3E-03	2.4E-02
1E-05	9.8E-03	4.2E-02	1.9E-02	1.1E-01	1.3E-02	8.5E-02	3.3E-02	2.4E-01
1E-04	9.8E-02	4.2E-01	1.9E-01	1.1E+00	1.3E-01	8.5E-01	3.3E-01	2.4E+00
Hazard Index Level:								
1.0	2.6E-02	6.7E-02	5.2E-02	1.7E-01	3.6E-02	1.4E-01	8.9E-02	3.8E-01

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Risk or Noncancer Hazard Index Level	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Risk Level:				
1E-06	5.0E-04	2.2E-03	9.4E-03	1.9E-02
1E-05	5.0E-03	2.2E-02	9.4E-02	1.9E-01
1E-04	5.0E-02	2.2E-01	9.4E-01	1.9E+00
Hazard Index Level:				
1.0	2.0E-02	8.7E-02	3.8E-01	7.5E-01

Notes:

All fish concentrations are in mg/kg.
Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.
EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.
Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.